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Nembrotha megalocera Yonow, 1990 - Red Sea

upper: *Nembrotha guttata* (orange spots) with the only Indian Ocean locality record of *N. cristata* (green spots), Maaya Tila, Ari Atoll, 6-8 m depth, March 1994 (photo H. Voigtmann); lower: *N. kubaryana*, Tulamben, Bali, Indonesia, July 2010 (photo K. Lee). Cover: *N. megalocera*, Red Sea (photo H. Sjøholm).

The genus *Nembrotha* (Bergh, 1877). The genus *Nembrotha* is widely distributed throughout the tropical Indo-West Pacific, characterised by bright colours and patterns. It belongs to the family Polyceridae, which are nudibranchs with a reduced mantle margin, the presence of a frontal veil or ridge, and a group of gills located forward or at the mid-dorsal point and have no pocket within which to retract. The rhinophores are lamellate, sometimes a contrasting colour to the body, and issue from a pocket with a raised rim which may be coloured. Many have large obvious oral tentacles, often in a contrasting colour. With a long 'tail' many species can swim using lateral flexions of the body. Species of *Nembrotha* appear to feed on ascidians: their radular teeth, a good diagnostic character for most other species and genera, are not very helpful in identification of species in this genus. The ribbon is narrow, with a broad central tooth, a large hooked lateral tooth on each side, and a short series of small outer lateral plates on each side. *N. megalocera* Yonow, 1990 is a species endemic to the Red Sea, and feeds on the violet ascidian *Diazona*. It is known to swim, but mating and spawning have not been recorded. It has similarly coloured sibling species in the Indian and Pacific oceans which never occur in the Red Sea; equally, *N. megalocera* has not been recorded outside the Red Sea, even in the Gulfs of Aden or Oman, which support a few Red Sea endemics. This is fairly typical of species of *Nembrotha*, some species having a very limited distribution and no external variation, whilst others have a large range and vary in colour and pattern. Another species with a very limited range is *N. guttata* Yonow, 1994, which is only found in one Indian Ocean island group, the Maldives archipelago. It belongs to a small group of black species which have coloured pustules, interesting because most species are linearly patterned. In this species the pustules are orange, with those around the frontal margin and on the head edged in green. *Nembrotha cristata* Bergh, 1877 is a Pacific species known only from the Maldives in the Indian Ocean, and has green pustules, green gills, and green rhinophore sheaths and tentacles. A third species in this colour group is *N. kubaryana* Bergh, 1877, found in both the Indian and Pacific oceans.

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Lizards and Eleonora's Falcon (*Falco eleonorae* Gené, 1839), a Mediterranean micro-insular commensalism

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ABSTRACT   Lizards and Eleonora's falcon occur on many Mediterranean islets. Data given in literature and new observations concerning their asymmetrical interactions, which have been reviewed and illustrated, allow to regard those as a commensal relationship typical on these micro-insular ecosystems. Some considerations on the ecological, ecomorphological and phenological traits involved on this commensalism are also briefly discussed.

KEY WORDS   Commensalism; lizards; *Falco eleonorae*; island ecology; Mediterranean.

INTRODUCTION

The Mediterranean micro-insular environments constitute an apparent paradigm of simplicity. Islets, usually hosting a low number of vertebrate species, are generally regarded as ecosystems characterized by chronic poorness in terms of trophic resources (Blondel et al., 2010).

This condition can impose severe ecological constraints to the species inhabiting the islets and, on the other hand, it stimulates a certain degree of flexibility and adaptability in their evolutionary responses.

For instance, the exposition to less potential competitors and predators, as well as the high population densities, which often occur on islets, may open new possibilities for enlarging trophic niche and/or for establishing peculiar ecological relationships among the island species.

Within the Mediterranean area, the lizards belonging to the suborder Sauria and the Eleonora's Falcon, *Falco eleonorae* Gené, 1839, are generally the unique representatives of Vertebrates in the faunal assemblages of islets, that also include rats and few seabirds species.

The present paper aims to review and update the knowledge concerning an apparently unusual relationship that occurs between these two emblematic inhabitants of the Mediterranean small island ecosystems (Fig. 1).

MATERIALS AND METHODS

Data from literature

Dionysades Archipelago (Crete, Greece)

The Dionysades (or Yianisadhes) Archipelago is situated 20 km north of the eastern end of Crete, and includes some uninhabited islets and rocks.

Among those, Paximada (314000 m^2, 136 m a.s.l.) harbours about 350 pairs of *Falco eleonorae* and represents one of the most important nesting site for the species at global level (Walter, 1979; Dimalexis et al., 2007); also, there is a large population of the endemic Cretan Wall Lizard, *Podarcis cretensis* Lymberakis et al., 2008 (see Lymberakis et al., 2008).
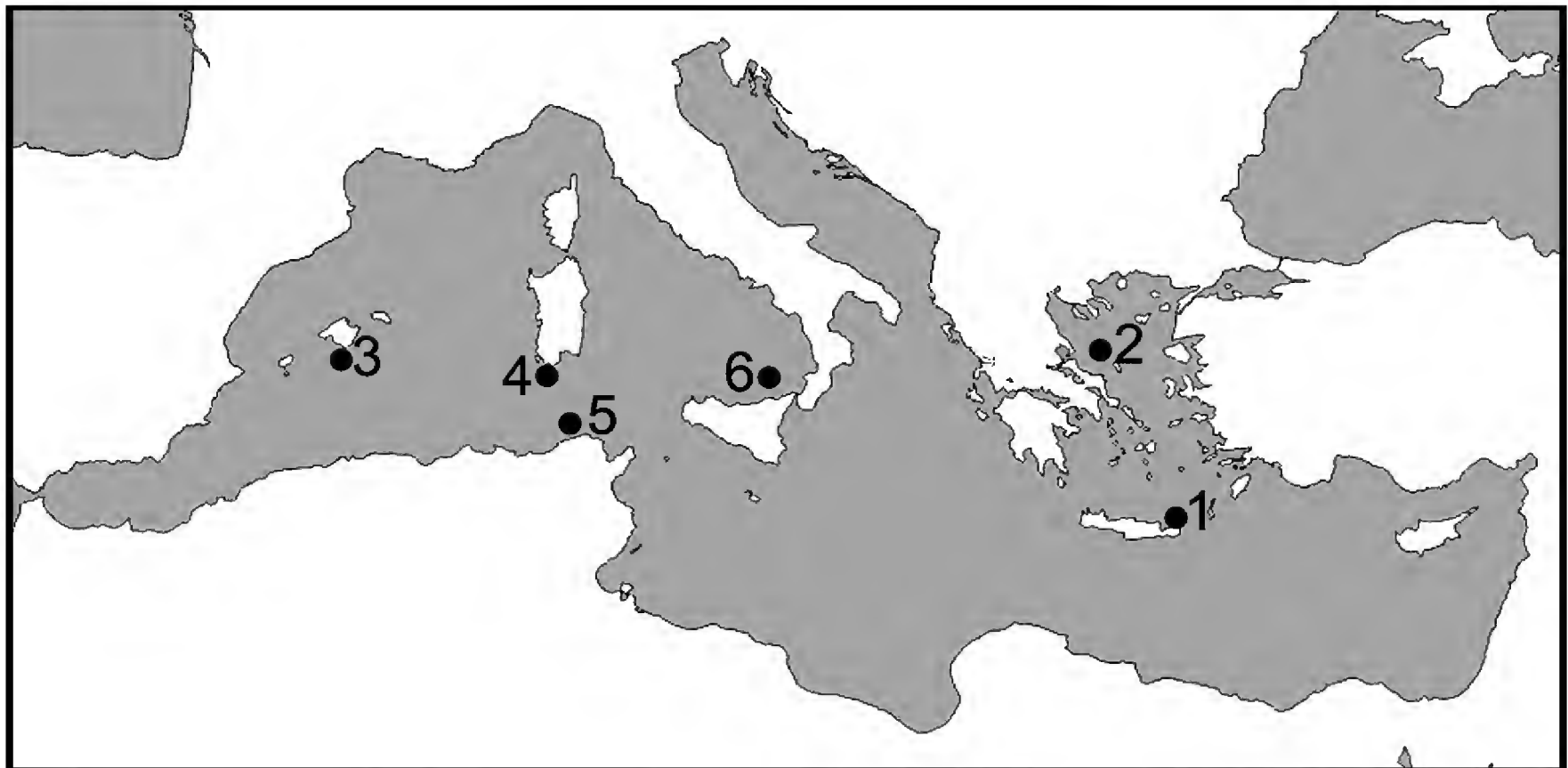
Figure 1. Geographical distribution of the sites where interactions between Eleonora's falcon and lizards have been observed. 1) Paximada; 2) Skantzoura islets; 3) Cabrera islets; 4) Il Toro; 5) Galita islets; 6) Scoglio Faraglione.

This islet has been intensely studied and monitorized since the Sixties by ornithologists. Walter (1967) has observed in summer a high concentration of lizards around the falcons' colony, which daily were looking for scraps of preys, fearless in entering on the nests even in the presence of adults.

According to this author, during the summer months on this islet, lizards feed largely with the help of falcons. In particular, he reports the case of an adult female of *Falco eleonorae* that plucked a prey in front a nest occupied by chicks, around which four lizards were eating the flesh remains attached to the carcass.

Another case concerns a lizard in the early morning that approached less than 20 cm to 15 days-aged falcons, that observed with interest but leaving it undisturbed, although the chicks usually eat everything that moves around the nest. However, he also found in a nest some dead lizards that showed visible signs of predation, but that have not been eaten by falcons.

As possible explanation given for this finding, the lizards may have approached too closely to the chicks (or adults) during meals and, hence, have been taken together with the prey and then thrown away. Walter (1967) concludes that these interactions can result partially unfavourable for the falcons, having observed how the preys placed few meters away from the nests are often quickly discovered and almost emptied by lizards.

Sporades Islands (Greece)

To Schultze-Westrum (1961) are due the first records regarding the interactions between lizards and Eleonora's falcon. This author has reported observations carried out in late September 1957 at Kyriagos, a tiny islet belonging to the uninhabited micro-archipelago of Skantzoura.

The local population of Erhard's Wall Lizard, *Podarcis erhardii* (Bedriaga, 1876), was almost exclusively concentrated around the colony, attracted by the remains of small birds preyed and deposited close to the nests, as well as by the insects occurring on the carcasses, while on the rest of the islet he did not see any lizard.

Schultze-Westrum (1961) emphasizes that the lizards were not scared by nestlings as well as by adult falcons that usually do not hunt near their nests, and considers such behaviour advantageous also for the Eleonora's Falcon, as indirect consequence of a continue cleaning from insects and food remains that would otherwise have rotted near the nests. Curiously, in a more recent paper Schultze-Westrum (2010) reminds similar behaviours for the

lizards of another satellite of Skantzoura, namely Strongylò, while doesn't mention his previous observations on Kyriagos. Both islets, occupied by medium-sized colonies of *Falco eleonorae* (Dimalexis et al., 2007), have a surface lesser than 1 ha and a maximum altitude of about 50 m a.s.l.

Finally, Valakos et al. (2008) have referred that on some islets of Sporades Archipelago also the endemic Skyros Wall Lizard, *Podarcis gaigeae* (Werner, 1930), lives in proximity of gulls and Eleonora's falcons, but not mentioning explicitly the occurrence of interactions among these animals.

Cabrera Archipelago (Balearic, Spain)

This group includes an island and some satellite islets situated around 10 km south of Mallorca (Balearic Islands) and hosting small colonies of Eleonora's Falcon (Suárez, 2001) and several populations of the endemic Lilford's Wall Lizard, *Podarcis lilfordi* (Günther, 1874).

A number of observations carried out at L'Imperial (30500 m², 73 m a.s.l.), Estels Xapat Gran (11300 m², 35 m a.s.l.) and Estels Xapat Petit (5700 m², 45 m a.s.l.), off the S and SE coast of Cabrera Gran, have been reported by Salvador (1980), which visited these islets in early September 1976. In one case, two lizards have translocated a carcass of Reed Warbler, *Acrocephalus scirpaceus* (Hermann, 1804), from a nest where it had just been deposited by an adult falcon.

Other cases involve observations of lizards who took the remains of preys in the nests and were chased away by falcons, but also others in which the lizards eat the remains of preys directly into the nests without being molested by adults in the hatching of nestlings.In addition, Salvador (1980) has found remains of Song Thrush, *Turdus philomelos* (Brehm, 1831), European Robin, *Erithacus rubecula* (Linnaeus, 1758), and other three unidentified birds in the stomach contents of some lizards from the islet Estels Des Dos Cols (5100 m², 35 m a.s.l.), where another small colony of *Falco eleonorae* occurs.

Il Toro Islet (Sardinia, Italy)

Il Toro islet represents the southernmost point of Sardinia and it is located 11 km S of Sant'An-

tioco Island. Its area is 132000 m² and maximum altitude is 112 m a.s.l.

The local colony of Eleonora's Falcon, composed by 70-80 nesting pairs, has a special historical significance, as the type-specimen on which was then described the species was captured in 1836 on this islet. Two episodes of interaction between the Tyrrhenian Wall Lizard, *Podarcis tiliguerta* (Gmelin, 1789), and Eleonora's Falcon have been documented by Fadda & Medda (2001).

During a visit to the islet in September 2000, these authors observed up to a maximum of six lizards engaged to contend the remains of a Blackcap, *Sylvia atricapilla* Linnaeus, 1758, a short distance from a falcon's nest.

Furthermore, some lizards were able to steal a prey, probably a warbler, brought by an adult in a nest, dragging out it despite the presence of nestlings. Similar cases were previously documented for the same site also by the naturalist photographer Domenico Ruju (in "Oasis", number 5, September/October 1998). For *Podarcis tiliguerta*, also Schneider (1986) has reported generically the occurrence of commensalism with Eleonora's Falcon.

New records

Galita Archipelago (Tunisia)

The Galita (or Jālitah) Archipelago is situated 50 km off the northern coast of Tunisia. This island group harbours about 80 nesting pairs of Eleonora's Falcon (Azafzaf, 2005) and some lizard species, without those belonging to the genus *Podarcis* (Lanza & Bruzzone, 1959; Delaugerre et al., 2011).

Many observations were recorded by one of us (RO) on the islets of La Fauchelle (136000 m², 137 m a.s.l.), Gallo (89000 m², 119 m a.s.l.), and Gallina (31000 m², 60 m a.s.l.), during several field researches carried out in September 1996, 1998 and 2001. In all the cases, the species interacting with *Falco eleonorae* was the Ocellated Skink, *Chalcides ocellatus* (Forskål, 1775) (Fig. 2).

The activity of skinks resulted generally intense in the surroundings of the colonies where nestlings were aged between few days and about 2 weeks. Inside the nests have been seen up to seven skinks simultaneously consuming the remains of passerine.

This foraging activity took place exclusively on ripped preys; only in one case, not directly related to interactions with falcons and observed at La Fauchelle, a skink has attempted to extract a dead but intact nestling from a nest of warblers.

Figure 2. *Chalcides ocellatus* feeds on remains of passerine in a falcon's nest; Gallo Islet, Galita Archipelago, September 2001 (photo R. Ouni).

Aeolian Archipelago (Sicily, Italy)

The archipelago is located 20 km off the northeastern coast of Sicily and comprises some islands and a number of islets; one of these, Scoglio Faraglione (5700 m², 33 m a.s.l.), is inhabited by the endemic Aeolian Wall Lizard, *Podarcis raffonei* (Mertens, 1952) and is frequently used as hunting territory and roost by the Eleonora's Falcon, which occurs nearby with 6-15 pairs in the island of Salina (Lo Cascio, 2000; Corso & Gustin, 2009).

During a visit on 28 October 2011, three of us (MD, FG & PLC) have observed for a long time several lizards eating the remains of a Common Stonechat, *Saxicola torquata* (Linnaeus, 1766), while they showed to ignore a killed but almost intact European Robin placed few centimetres away.

The stonechat, although rather fresh, was already partially decomposed in the gash of the head, containing ants and some larvae of flies (probably calliphorids), while this latter perhaps had been just recently left over by a falcon disturbed by our coming. The occurrence of this food source has led to a series of complex intraspecific interactions (Figs. 4-5): a robust male lizard was very aggressive versus other males as they approached the prey but, at the same time, allowing some females to feed on the carcass. Initially, lizards have surely ingested larvae and ants, but most time has been dedicated to an intense consumption of fleshy pieces (Fig. 3) and feathers (Fig. 6).

During the consumption, the prey is dragged from its original location by a lizard (Fig. 7); for another islet of the same archipelago, La Canna (3400 m², 70 m a.s.l.), inhabited both by Aeolian wall lizard and by Eleonora's Falcon, Capula & Lo Cascio (2011) have previously reported that lizards often prey upon flies and other insects attracted by falcon pellets.

DISCUSSION

The complex of interactions occurring between Eleonora's Falcon and lizards has been differently interpreted by authors, e.g. as mutualism (Schultze-Westrum, 1961; 2010), symbiosis (Salvador, 1980), or kleptoparasitism (Fadda & Medda, 2001), while only Walter (1979: 19) has regarded the lizards as "true commensals" of *Falco eleonorae*.

Positive interactions among two species include all non-consumptive interactions benefiting at least one of the associated species but not impacting the other; especially in the case of commensal interactions, one species benefits and the other is unaffected (Dickman, 1992; Bertness & Callaway, 1994).

From this point of view, all the above mentioned cases which have been documented for lizards and falcons in the Mediterranean islets seem to fit well to the widely accepted mean of commensalism. Anyhow, access to food source by lizards has occasionally involved its removal, outlining an asymmetrical interaction that can be assimilated to kleptoparasitism, although it likely began as a nonantagonistic relationship among these species.

Possible or confirmed commensal interactions between birds and reptiles are quite uncommon (Thomas, 1890; Attwell, 1966; Christian, 1980 and references therein; Gehlbach & Baldridge, 1987; Gory, 2009), mostly of which may be truly referred to cleaning symbiosis (sensu MacFarland & Reeder, 1974) rather than trophic commensalism.

This is perhaps also the case of interactions between gulls and lizards reported by Kammerer (1925) for some Adriatic islets, where the latter have been observed eating ectoparasites of nestlings.
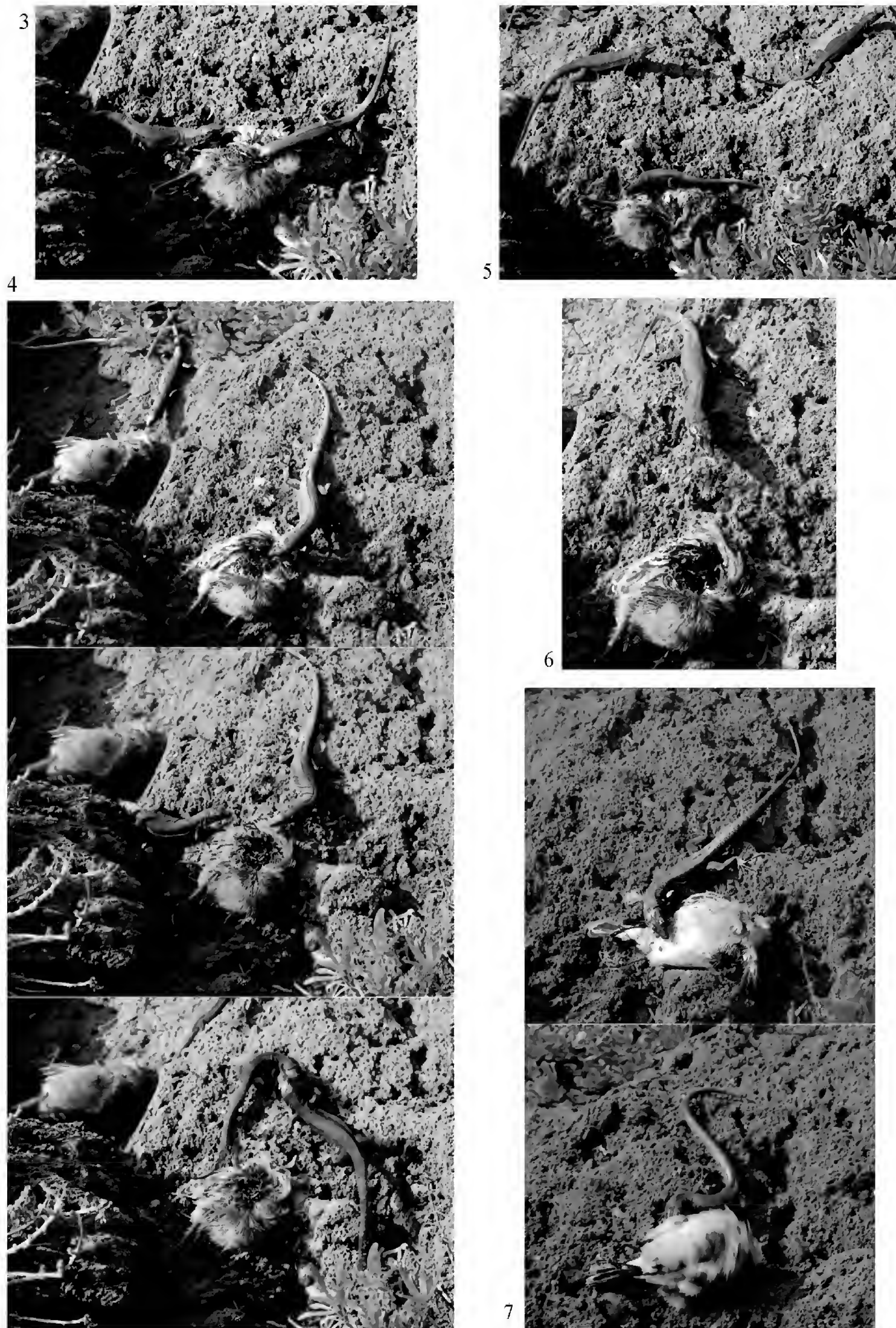
Figure 3. Two *Podarcis raffonei* on the carcass of a Common Stonechat preyed by Eleonora's Falcon; Scoglio Faraglione Islet, Aeolian Archipelago, October 2011 (photo P. Lo Cascio). Figure 4. Intraspecific interactions between two specimens of *Podarcis raffonei*: above, the first lizard feeds on the carcass of a stonechat while the second (top left) approaching that of a robin; in the middle, the second has neglected the robin and approaches the other one, even if already occupied by the first lizard; below, the first attacks the second, showing a territorial behaviour. Figure 5. Another territorial behaviour: a male (top left) and a female basking near the stonechat's remains while another female is feeding on the carcass. Figure 6. A male eats a feather; to better perform the swallowing, the lizard repeatedly rubs its snout on the rocky soil. Figure 7. During the consumption, the prey is dragged from its original location by a lizard.

In this perspective, the occurrence of commensalism between lizards and Eleonora's Falcon takes on particular interest, both for the extreme rarity of this interspecific relationship among these animals and its uniqueness in the context of the Mediterranean.

Eleonora's Falcon is a medium-sized, colonial raptor, which from April-June to October-November occupies its breeding sites distributed in an area ranging from Cyprus to Canary Islands.

Islets, especially those of the Aegean Sea that harbour about 70% of its global population (estimated as 6800-7400 pairs, see Burfield & Kreiser, 2004; Ristow, 2010), are crucial ecosystems for this species, which needs isolation and the feeling of security to nest and breed successfully. Indeed, the difficult access to remote slopes of small islands minimizes the human presence in these areas.

Falco eleonorae is basically insectivorous; however, in coincidence with the hatching of chicks, it preys almost exclusively upon passerine birds that in late summer cross the Mediterranean during the migration (Walter, 1979; Ristow et al., 1986).

Lizards are widely represented on the Mediterranean insular ecosystems, in particular those belonging to the clade Gekkota as well as to some genera (such as the lacertid *Podarcis* Wagler, 1830 and the scincid *Chalcides* Laurenti, 1768), but islets are generally inhabited by few or even one species (see Corti et al., 2006; Delaugerre & Cheylan, 1992; Mateo, 1997; Mayol, 1997; Valakos et al., 2008).

Although their main food source is represented by a wide variety of invertebrates, lacertid and scincid lizards can have unusual feeding behaviours, especially among islet populations.They include herbivorism (Pérez-Mellado & Corti, 1993; Sáez & Traveset, 1995; Van Damme, 1999; Lo Cascio et al., 2008), kleptoparasitism (Cooper & Pérez-Mellado, 2003), cannibalism (Castilla & Van Damme, 1996; Pafilis et al., 2009; Dappen, 2011) or attacks to dangerous preys normally avoided from lizards (Castilla et al., 2008).

Also, a certain propensity to the consumption of blood, fleshy remains and organic matter of vertebrates by insular lizards has been empirically documented: e.g., on Lampione Islet (Channel of Sicily), Moltoni (1970: 167) has found a maltese wall lizard, *Podarcis filfolensis* (Bedriaga, 1876), licking "i liquidi che uscivano da un uovo nel quale il piccolo aveva già rotto il guscio" [the fluids issuing

from an egg in which the chick had already broken the shell]; and on Galitone, one of the islets belonging to the Galita Archipelago, Captain Enrico D'Albertis noted that two lizard species, *Chalcides ocellatus* and the Large Psammodromus, *Psammodromus algirus* (Linnaeus, 1758), were mighty attracted by the blood of falcons stored into his game-bag: "allora spiumato un uccelletto che avevo trovato presso un nido ne posi il corpicino nella reticella da farfalle che portavo meco e tenni il manico di questa in una mano ... non tardarono le incaute bestiole a slanciarsi sulla preda" [then, plucking a bird that I had found in a nest, I put it in a butterfly net that I had and held the handle in one hand ... the misguided creatures were not slow to rush on the prey] (D'Albertis, 1878: 307).

A first, distinctive trait of the commensal interaction between Eleonora's Falcon and lizards is its brief temporal context. Indeed, all the reported observations were done in September-October, when i) the diet of falcons becomes strictly ornithophagous, and ii) the prey availability for lizards is substantially reduced (see Lo Cascio & Capula, 2011) and, therefore, the organic material carried onto islets by falcons may represent a significant nourishment.

Lizards can use this additional source of food not only if they live near the colonies, but also when inhabiting areas regularly used as roosts by falcons, such as in the case of Scoglio Faraglione Islet. Other noteworthy trait is represented by the relatively large number of species so far recorded to be involved as commensals in this interaction: five of these belong to the lacertid genus *Podarcis*, and one is the scincid *Chalcides ocellatus*.

This latter differs greatly from the others both morphologically and ecologically: in fact, the ocellated skink is described as semi-fossorial, sit-and-wait forager in plant litter or under stones (Arnold, 1984; Kalboussi & Nouira, 2004; Lo Cascio et al., 2008), whereas the foraging activity of lacertids mainly occurs on the surface (Pérez-Mellado & Corti, 1993).

Nevertheless, both for *Podarcis* and for *Chalcides*, access to this food source involves an outstanding effort in bite performance, because their dentition smoothed and sharp mainly facilitates the crushing (see Caputo, 2004; Metzger & Herrel, 2005). Observations carried out at Scoglio Faraglione, where lizards have preferred a partially gashed bird but

completely avoided another intact prey, may be explained with this morphological constrain and, especially, with the difficulty of ripping fleshy pieces from a plumed and more compact tissue.

A still open question, however, is whether this seasonal switch from insectivory/arthropodivory to true carnivory may be accompanied by phenotypic specialisations in the trophic apparatus (Schwenk, 2000). Gut anatomy, enzymatic activity, microbiota of the gastrointestinal tract may be involved by physiological adjustments to a different diet (Karasov & Diamond, 1988; Karasov et al., 2011; see also Pough, 1973).

Little information available on gastrointestinal parasites of some lizard populations have so far shown just their characterization as species typically associated to animals with insectivorous rather than herbivorous diet (Roca & Hornero, 1994; Roca et al., 2006), but didn't give any indication on this concern.

In contrast, a factor which may have encouraged the establishment of these interactions is represented by the low risk for the lizards to be predated by falcons.

Although some cases are given in literature (Krüper, 1864; Araujo et al., 1977; Walter, 1979; Salvador, 1980; Dolç Garcia & Dies Jambrino, 1991; Lo Cascio, 2000), there are no doubt that lizards appear with negligible percentages in the trophic spectrum of Eleonora's falcon; Walter (1979) also observed that all the died lizards found in nests were essentially untouched except for head and back injuries, and remarks that these evidences suggest as lizard should not be a food item of falcons, but an occasional nuisance.

Besides, attendance in proximity to colonies may provide an indirect protection from other bird species that are primarily lacertophagous, such as the Kestrel, *Falco tinnunculus* Linnaeus, 1758, which usually are chased out from the breeding sites by the Eleonora's falcon.

The balance among these factors has probably enhanced the development of commensal interactions between lizards and falcons, both characterized by a long history of coexistence in small insular ecosystems since many thousands of years (Bailón, 2004; Sánchez Marco, 2004 and references therein). The occurrence of these interactions has been so far documented for some islets, as reported in this paper, but it could result probably more widespread

in the Mediterranean, as suggested by the recurring finding of feathers and small plumes in the examined faecal pellets of lizards cohabiting with *Falco eleonorae* on islets such as Strombolicchio, in the Aeolian Archipelago, and Lampione, in the Channel of Sicily (PLC, unpublished data).

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Nematodes in aquatic environments: adaptations and survival strategies

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ABSTRACT

Nematodes are found in all substrata and sediment types with fairly large number of species that are of considerable ecological importance. Despite their simple body organization, they are the most complex forms with many metabolic and developmental processes comparable to higher taxa. Phylum Nematoda represents a diverse array of taxa present in subterranean environment. It is due to the formative constraints to which these individuals are exposed in the interstitial system of medium and coarse sediments that they show pertinent characteristic features to survive successfully in aquatic environments. They represent great degree of morphological adaptations including those associated with cuticle, sensilla, pseudocoelomic inclusions, stoma, pharynx and tail. Their life cycles as well as development seem to be entrained to the environment type. Besides exhibiting feeding adaptations according to the substrata and sediment type and the kind of food available, the aquatic nematodes tend to withstand various stresses by undergoing cryobiosis, osmobiosis, anoxybiosis as well as thiobiosis involving sulphide detoxification mechanism.

INTRODUCTION

The diversity of animal life is not distributed uniformly across the world and its diversification is not an automated process but requires some characteristics of form and function that allow successful exploitation of new habitats. Such species are, therefore, considered "plastic" or "malleable" that with modifiable genetic material can change or adapt when subjected to evolutionary selective pressures. Nematodes, the most numerous of all Metazoa in number of individuals, exist in all habitats that can support life.

Being ubiquitous, they can be as dynamic as the habitat types and can change through time. With a deceptively simple anatomical design, they are referred as typical representatives of Metazoa (Nelson et al., 1982). However, they are the most complex forms with many metabolic and developmental pro-

cesses comparable to higher taxa; they demonstrate remarkable abilities to withstand stress and adverse conditions. The nematode *Caenorhabditis elegans* (Maupas, 1900) survived the crash of space shuttl, Columbia that hit the ground with an impact 2,295 times the force of Earth's gravity (Cosgrove-Mather, 2003).

Many species survive the unfavourable conditions by demonstrating anhydrobiosis, cryptobiosis, osmobiosis or cryobiosis. The key to their success in all types of ecosystems and biotopes is their morphological plasticity, physiological adaptability and ecological diversity.

Nematodes are basically aquatic animals that require a film of water to move. They may exist as free-living, commensals or parasites in all types of aquatic habitats viz., freshwater, brackish, marine systems; in extreme environments including sea-ice to hydrothermal vents. They may be found in clay,

gravel, epiphytes, on sea grasses and algae. Their vermiform, soft and flexible bodies are well suited to allow bending in the interstitial system of sand grains/particles (Heip et al., 1985; Strayer, 1985; Traunspurger, 1996 a, b).

A number of factors affect their distribution viz., seasons, latitude, water depth, geochemical properties of the sediment, temperature, salinity, water movement, oxygen content, species interaction, resource partitioning and predation (Jensen, 1981; 1987a; Joint et al., 1982; Bouwman et al., 1984; Platt & Lambshead, 1985; Ólafsson, 1992; Giere, 1993; Hendelberg & Jensen, 1993; Soetaert et al., 1994; Modig & Ólafsson, 1998; Steyaert et al., 1999; Wetzel et al., 2002; Armenteros et al., 2009).

The present article highlights the habitat-specific features of aquatic nematodes, their adaptations and compatibility to the environmental conditions.

Major aquatic groups

Phylum Nematoda includes a diverse array of taxa specific to a variety of aquatic habitats. The typical composition of the freshwater meiofauna differs much from that in marine realm with nematodes more numerous in sediments than in the water columns (Bell & Sherman, 1980; Sibert, 1981). Most species of *Chromadorea* are found in fresh water ecosystems with the exception of few tylenchids, aphelenchids and rhabditids whereas only few species are reported from polar freshwaters (Maslen, 1979).

The species of Araeolaimida, Monhysterida as well as Chromadorida inhabit both fresh water as well as marine environments (De Ley et al., 2005). In Enoplea, the fresh water representatives mainly belong to Triplonchida, Mononchida, Dorylaimida and Mermithida and to a lesser extent Enoplida. The taxa Enoplida, Desmoscolecida, Chromadorida and Monhysterida are predominantly marine. About 4000 species of free-living marine forms have been accounted through various faunal surveys (Jensen, 1981; Sharma & Webster, 1983; Vanreusel et al., 1992). Estuarine nematodes show greater taxonomic affinities to freshwater nematodes and can tolerate significant changes in salinity (Forster, 1998; Warwick, 1981a).

The nematode species with fresh water affiliations are most abundant at the upper edge of the intertidal zone where the marine influence is often weak (Nicholas et al., 1992).

Morphological characteristics

The aquatic nematodes are quite varied morphologically and no single species can be considered a true representative. However, the similarity in fresh water as well as marine forms on account of their aquatic habitats reflects convergent evolution. Most aquatic nematodes have elongated cylindrical bodies of about one to several millimeters length except ~9 m long whale parasite *Placentonema gigantissima* (Gubanov, 1951). The dark subterranean environment has led to loss or reduction in body pigmentation, hence, the nematodes appear whitish-semi transparent or transparent.

They are characterized by slender, spindle-shaped bodies with enhanced swimming abilities. Wriggling or undulatory propulsion by alternate pushing and bending, is typically found due to presence of only longitudinal musculature. However, some aquatic species can "jump" by bending of their bodies followed by a sudden relaxation (e.g. *Theristus*).

The members of Epsilonematidae and Draconematidae move by "looping" with an alternate adhesion and detachment of their anterior and posterior body ends whereas the desmoscolecids move by contractive waves.

The cuticle of aquatic nematodes may be smooth (most Enoplidae), annulated (Desmodoridae, Desmoscolecidae, most Monhysteridae), punctated (Cyatholaimidae, many Chromadoridae, Comesomatidae), or provided with complicated and compact structures (many Chromadoridae).

There may be diverse types of cuticular modifications (Figs. 1-3, 5, 9, 10). Some nematodes may have longitudinal ridges or alae (Figs. 11-13, 15, 16, 18) aiding in swimming. Punctations in the form of dots (punctation) or pores arranged irregularly or in rows, are also common in many aquatic taxa (Figs. 8, 9, 14). The punctations may fuse into compact structures in many chromadorids (e.g., *Spilophorella paradoxa* de Man, 1888; *Chromadorella* spp.). Often the cuticular surface is covered with a dense "fur" of ectosymbiotic sulfur-oxidizing bacteria to thrive in sulfur-rich marine sediments (Nussbaumer et al., 2004; Ott et al., 2008).

Aquatic nematodes usually possess long, hair-like sensilla called setae, relatively more developed in marine forms, compared to slightly-raised or mammellate sensilla of terrestrial nematodes. Body (somatic) sensilla (commonly found in Monhysterida,
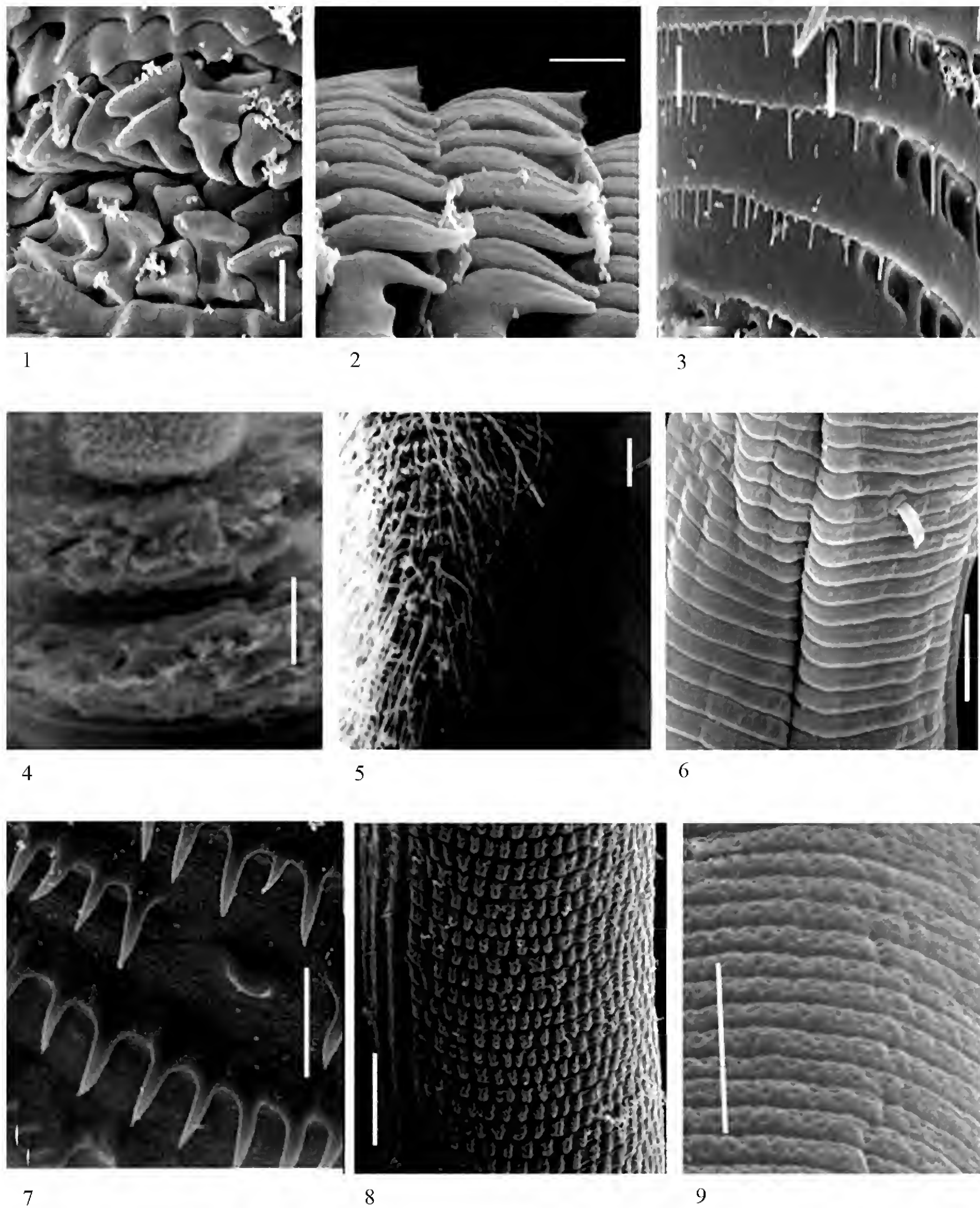
Figures 1-9. Cuticular modifications.
Figs. 1-3: *Epsilonema pustulatum* after Karssen et al. 2000. Fig. 4: *Desmoscolex* sp. Fig. 5: *Glochinema* sp.
Fig. 6: *Plectus* sp. Fig. 7: *Goezia leporini* after Martins and Yoshitoshi, 2003. Fig. 8: *Cruznema* sp. Fig. 9: *Achromadora* sp. (Scale bar: 1-3, 7 =1 μm; 4-6, 8, 9 = 10 μm).
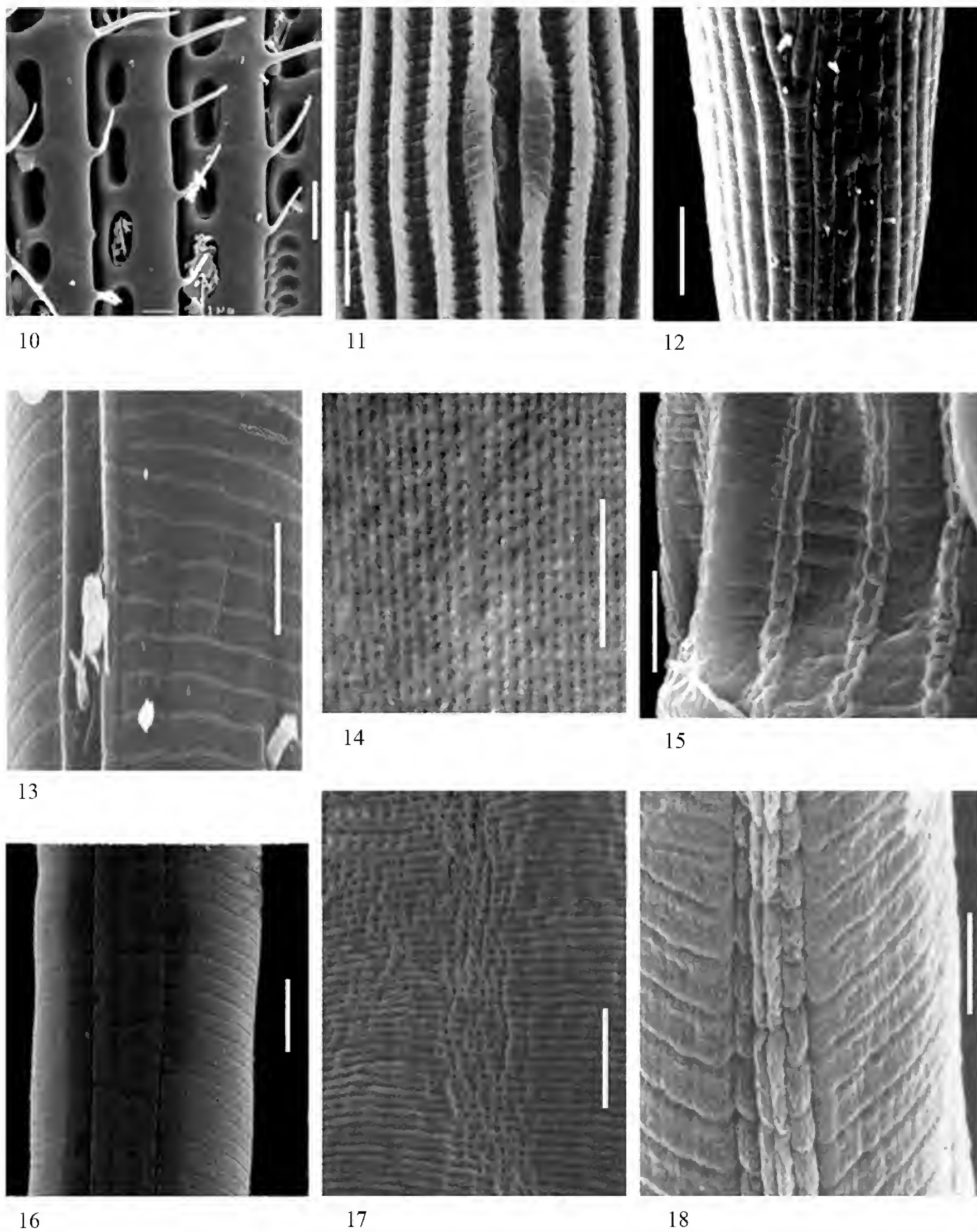
Figures 10-18. Cuticular modifications.
Fig. 10: *Epsilonema pustulatum* after Karssen et al., 2000. Fig. 11: *Mononchoides* sp. Fig. 12: *Fictor* sp.
Fig. 13: *Plectus zelli*. Fig. 14: *Pelodera teres*. Fig. 15: *Diplogastrellus* sp. Fig. 16: *Panagrellus* sp. Fig. 17: *Dorylaimus*
sp. Fig. 18: *Chiloplacus* sp. (Scale bar: 10 = 1 μm; 11-18 = 10 μm).

Araeolaimida, Chromadorida and Enoplida) may be arranged in rows or distributed randomly; in absence of eyes, the symmetry of the tactile sensilla and the flexible body serve to guide the crawling worm between sand grains, debris etc. In aquatic habitats the nematode setae of 5 to 10 μm length dominate with shortest setae mostly found in nematodes of littoral zone. Other types of sensilla include caudal setae (Figs. 110, 111) and terminal setae (Figs. 102, 111, 113, 114, 117).

The terrestrial nematodes usually have the primitive arrangement (Fig. 32) of labial sensilla (6 inner labials + 6 outer labials + 4 cephalics) contrary to the configuration in many aquatic nematodes (6 + 10) where outer labials are situated at the level of cephalic sensilla (Fig. 23) or there may be additional setae (Figs. 24, 28). The jointed setae (Fig. 23) found in some aquatic nematodes are comparable to jointed appendages of arthropods indicating some relationship among these ecdysozoans.

Amphids, the bilaterally symmetrical sensory structures demonstrating the first evidence of cilia, are involved in many behavioural functions and are comparable to olfactory organs. Coomans (1979) suggested a mechanoreceptive, secretory as well as photoreceptive function to amphids.

In aquatic nematodes, the amphids are relatively complex, conspicuous and post-labial and mainly circular (Figs. 20, 22, 28), loop-shaped (Figs. 72, 73), spiral, (Figs. 64, 65, 78), shepherd's crook, pocket-like and rarely pore-like compared to the amphids of land-dwelling nematodes that are usually pore-like or slit-like (Figs. 25, 31, 32) and occasionally round or spiral-shaped. Although there is little physiological evidence for photosensitivity in nematodes, ocelli have been defined as discrete photoreceptors (Croll, 1970) and commonly found in marine genera viz., *Thoracostoma* Marion, 1870, *Phanoderma* Bastian, 1865, *Eurystomina* Filipjev, 1921, *Calyptronema* Filipjev, 1921 etc.

Species may be provided with compact conglomerations of pigments (Figs. 81, 94, 95) viz., *Enoplus* spp., *Pseudocella trichodes* (Leuckart, 1849), with diffuse pigments in the cervical region inside pharynx (*Deontostoma* Filipjev, 1925; *Oncholaimus* Dujardin, 1845 and *Chromadorina* Filipjev, 1918) or outside pharynx in epidermis/pseudocoelom (*Araeolaimus* de Man, 1888). Eye spots are often provided with a hyaline "lens" or comparable structure (Fig. 93) e.g., *Symplocostoma* Bastian, 1865 and *Araeolaimus*.

The utility of ocelli in aquatic habitats with particular reference to marine environment, is the negative phototaxis to move to deeper layers/strata, as observed in *Chromadorina bioculata* (Schultze in Carus, 1857); *Oncholaimus vesicarius* (Wieser, 1959); *Enoplus anisospiculus* Nelson et al., 1972 (Croll, 1966; Croll et al., 1972; Bollerup & Burr, 1979; Burr & Burr, 1975; Burr, 1979; Burr, 1984). It probably explains the absence of ocelli in nematodes inhabiting littoral sand. Few nematodes use photosensitivity to determine the photoperiod for successful completion of life cycle. Haemoglobin instead of melanin, in some nematodes including mermithids, serves an optical and light-shadowing function (Ellenby, 1964; Ellenby & Smith, 1966; Croll & Smith, 1975; Burr et al., 2000).

The metanemes (Fig. 92) are spindle-shaped/filamentous proprioceptors (Hope & Gardiner, 1982) or stretch receptors (Lorenzen, 1978, 1981), found in the lateral hypodermal chords of marine enoplids (e.g., *Enoplus* Dujardin, 1845; *Deontostoma* and *Oxyonchus* Filipjev, 1927) lying parallel or at an angle of 10-30° to the main body axis. Metanemes are sensitive to the dorsoventral bending of nematode body thus controlling the body volume.

Some marine enoplids especially Thoracostomopsidae possess a pair of sense organs known as cephalic slits (de Man, 1886) or cephalic organs (Filipjev, 1927), latero-ventrally placed between the circlets of the labial sensilla (Fig. 96). The cephalic organs may possess club-shaped cirri (chemosensory/mechanosensory) in species having powerful buccal armature (Wieser, 1953) e.g., *Oxyonchus dentatus* (Ditlevsen, 1918) Filipjev, 1927.

Crystalloids (Figs. 82, 83), the crystal-like inclusions or irregular electron dense deposits (Fig. 84) occurring subcutaneously or in pseudocoelom, have been observed in many fresh water (e.g., *Monhystera* Bastian, 1865; *Ironus* Bastian, 1865; *Tobrilus* Andrássy, 1959; *Tripyla* Bastian, 1865) sensu Alekseyev and Dizendorf, 1981; Andrássy 1958, 1981, 1984; Juget, 1969; Micoletzky, 1922, 1925; Riemann, 1970; Jacobs & Heyns, 1990) and marine nematodes e.g., *Sabatieria* Rouville, 1903; *Sphaerolaimus* Bastian, 1865; *Terschellingia* de Man, 1888 (Nicholas et al., 1987). The ultrastructural, ecophysiological and physical microanalysis further revealed high sulphur content of the osmiophilic and homogeneous crystalloids (Nuss & Trimkowski, 1984). Other reports suggested their role in detoxification or preventing harmful accumulation of

metal sulphides in the tissues (Nuss, 1984; Nicholas et al., 1987) or in storing food during adverse conditions (Bird et al., 1991).

Body pores (Figs. 85, 86) are common among many *Enoplea*. Generally a body pore leads through a canal to a unicellular, merocrine hypodermal gland (Fig. 87) and an associated bipolar neurocyte e.g., *Chromadorina germanica* (Butschli, 1874). However, Electron Microscopy revealed multivesicular complexes similar to Golgi bodies (Lippens, 1974). Some marine worms e.g., *Ptycholaimellus ponticus* (Filipjev, 1922) Gerlach, 1955 with a system of body pores and hypodermal glands modify the sedimentary microenvironments by building tubes (Hope & Murphy, 1969).

The diversity in nematodes revolves mostly around the evolution of stoma and one or more pharyngeal bulbs. The stoma or buccal cavity, usually a triradiate structure bounded by three or six lips, exhibits variations reflecting the different feeding modes (Wieser, 1953; Jensen, 1987b; Moens & Vincx, 1997; Traunspurger, 1997.

The buccal cavity may be absent or minute (Figs. 48-51) to spacious, unarmed type (Figs. 33, 34) in non selective deposit feeder species. The nematodes feeding on diatoms possess a buccal cavity armed with small to moderate-sized teeth (Jensen, 1982; Romeyn & Bouwman, 1983; Romeyn et al., 1983; Moens & Vincx, 1997). The buccal cavities of powerful predators may further be armed with immoveable armature/teeth (Figs. 37-40, 52-59), rows of small denticles or moveable structures termed mandibles or jaws (Figs. 60, 63).

Pharynx, the anterior muscular part of the gut with a tri-radiate lumen does not show habitat-wise specificity but largely varies according to the feeding modes. In marine nematodes the pharynx is largely cylindrical with posterior part gradually expanding, occasionally forming a muscular bulb. The dorsal gland orifice usually opens through the stegostom while pharyngeal gland nuclei are located in basal part. The pharyngeo-intestinal junction (cardia) and intestine do not show aquatic adaptations.

The secretory-excretory cell (renette cell = ventral gland, cervical gland or excretory cell) opens through a ventral pore between mid pharynx to anterior intestine (Bird & Bird, 1991) except *Monhystera disjuncta* Bastian, 1865 and some Ironidae having a labial location (Van de Velde & Coomans, 1987). In marine nematodes, the well developed renette cell has secretory role in tube-building e.g., *Ptycholaimellus* Cobb, 1920 (Jensen, 1988). The secretory role has been also verified in *Sphaerolaimus gracilis* de Man, 1876 (Turpeenniemi & Hyvärinen, 1996) and *Monhystera disjuncta* (Van De Velde & Coomans, 1987).

The number and structure of ovaries along with other genital components though taxonomically important, do not show much difference from those of terrestrial nematodes and are largely specific of higher taxa (Lorenzen, 1981, 1994). Ovaries in aquatic nematodes generally tend to be long and well developed reflecting high fecundity. Likewise the position of vulva usually varies from middle (e.g., members of Tobrilidae, Plectidae etc.) to posterior (e.g., monhysterids) in aquatic nematodes.

The females are usually didelphic-amphidelphic with antidromously reflexed (outstretched in *Cytolaimium exile* Cobb, 1920) ovaries. However, monhysterids represent mono-prodelphic females while the gonad can be mono-opisthodelphic in most species of Alaimidae. There is a connection between the reproductive and digestive systems in some Oncholaimidae through demanian system (Figs. 97-101), which varies from simple (e.g., *Viscosia* de Man, 1890) to highly-developed one (e.g., *Adoncholaimus* Filipjev, 1918 and *Oncholaimus*).

The demanian system serves the functions of maintaining viability of spermatozoa, releasing a sex attractant, facilitating egg deposition and transfer of sperm to the intestine, and elimination of excess sperms deposited in females through the digestive system (Eyualem et al., 2006). The aquatic male nematodes may possess one (monorchic) or two (diorchic) testes largely depending on the taxonomic group they belong to. Typically, the cuticularised spicules and gubernaculum and the genital supplements/papillae are also not habitat-specific.

Most aquatic nematodes possess long filamentous tails and propel themselves faster by its whipping action (Gerlach, 1953, 1971; Wieser, 1959; Warwick, 1971; Riemann, 1974). Nevertheless, the tail shape can be variable from round, conical, cylindroid-clavate to elongated-filiform (Figs. 102-112). In most marine nematodes it may be provided with caudal setae, specifically confined to terminus as terminal setae (Fig. 111). Often the bluntly-rounded tail terminus bears a spinneret- the outlet for caudal glands' (Figs. 113-117) sticky secretion (Distem) that helps in anchorage to an object or substratum. This phenomenon of nictation is a foraging adaptation in aquatic nematodes.
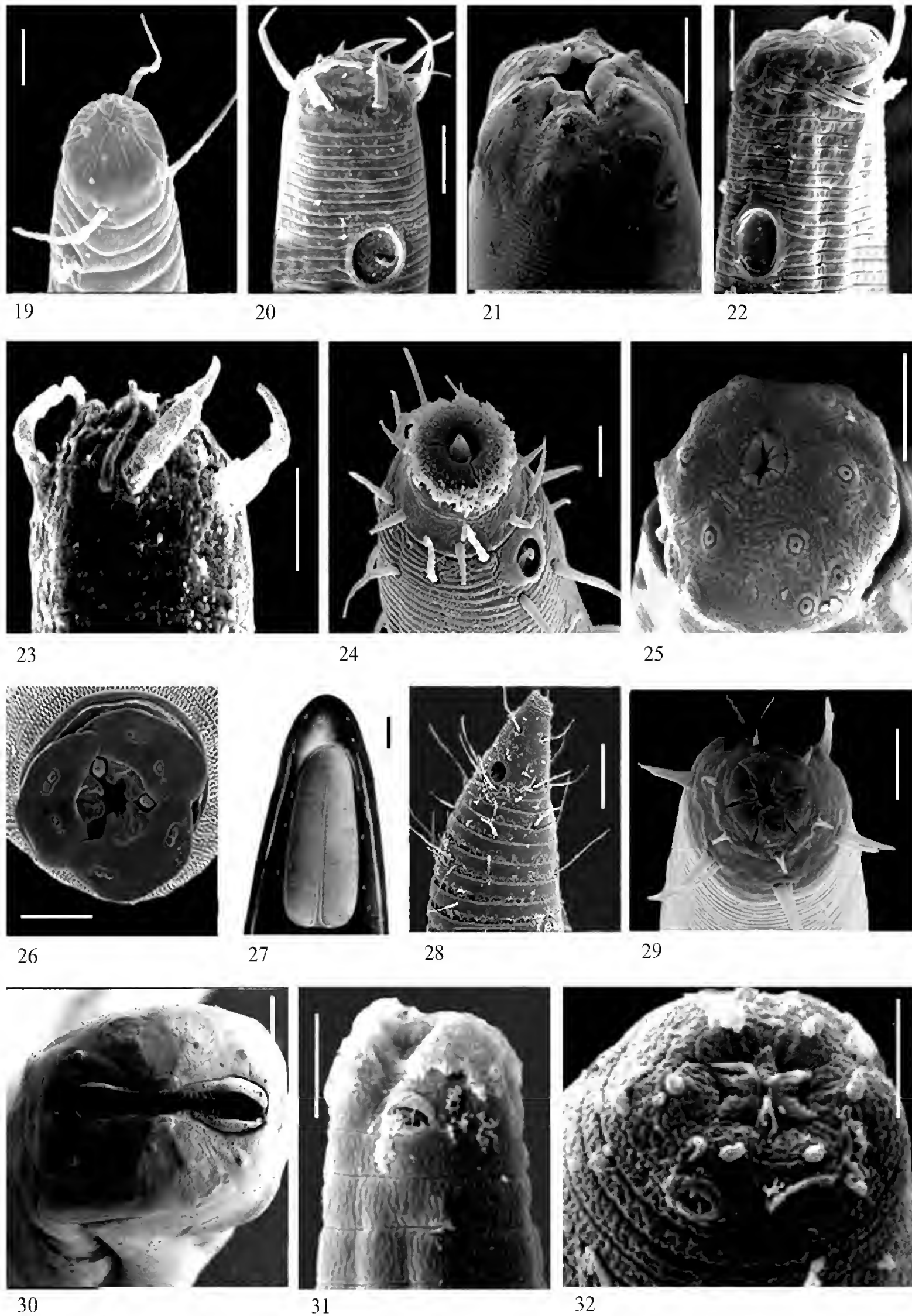
Figures 19-32. Modifications in anterior sensilla.
Fig. 19: *Chronogaster* sp. Fig. 20: *Monhystera* sp. Fig. 21: *Mononchus aquaticus*. Fig. 22: *Hoffmanneria* sp. Fig. 23: *Prismatolaimus* sp. Fig. 24: *Sabatieria lyonessa*. Fig. 25: *Xiphinema* sp. Fig. 26: *Goezia leporini* after Martins & Yoshitoshi, 2003. Fig. 27: *Rhaptothyreus* sp. Fig. 28: *Epsilonema pustulatum* after Karssen et al., 2000. Fig. 29: *Theristus* sp. www.nem.wur.nl/UK/In+the+picture/Gallery/. Fig. 30: *Camallanus tridentatus* after Santos & Moravec, 2009. Fig. 31: *Cephalobus* sp. Fig. 32: *Myctolaimus kishtwarensis* Hussain, Tahseen, Khan & Jairajpuri, 2004(Scale bar = 10 μm).
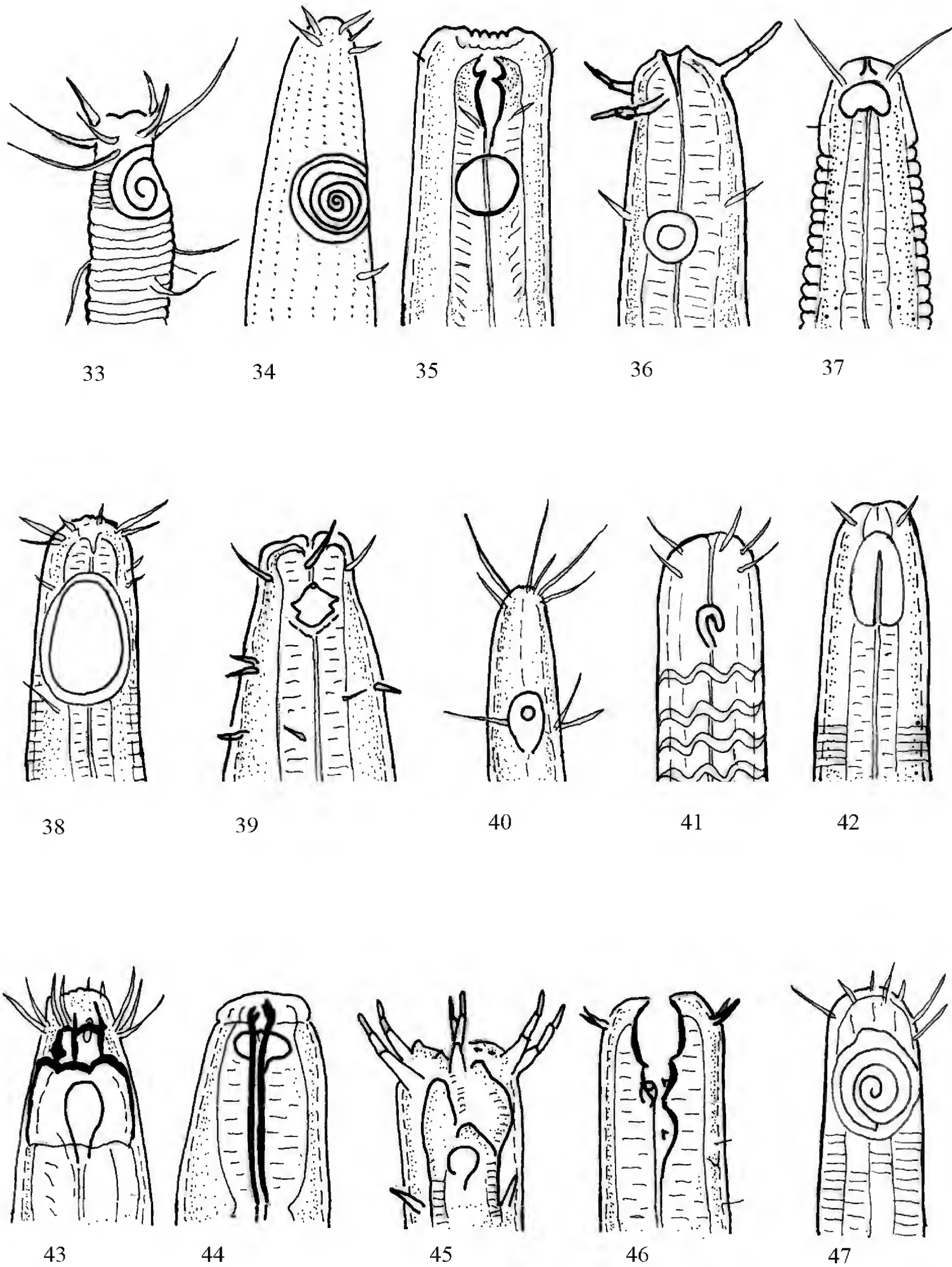
Figures 33-47. Modifications in anterior sensilla.
Fig. 33: *Paramesonchium* sp. Fig. 34: *Cervonema* sp. Fig. 35: *Prodesmodora* sp. Fig. 36: *Rhabdocoma* sp. Fig. 37: *Apha-nolaimus* sp. Fig. 38: *Amphimonhystera* sp. Fig. 39: *Platycoma* sp. Fig. 40: *Wieseria* sp. Fig. 41: *Ceramonema* sp.;
Fig. 42: *Diplopeltoides* sp. Fig. 43: *Paramesacanthion* sp. Fig. 44: *Pheronous* sp. Fig. 45: *Cyatholaimium* sp. Fig. 46: *To-brilus* sp. Fig. 47: *Coninckia* sp.

Reproduction and development

Reproductive mechanisms do differ among nematodes in different habitats. Mostly marine nematodes are dioecious and amphimictic with obligate bisexuality thus enhancing the chances of fertilization and promoting high genetic variation. However, sex ratio is significantly influenced by temperature in *Pellioditis marina* Bastian, 1865 (Rhabditidae) and *Diplolaimelloides meyli* Timm, 1961 (Monhysteridae), with more males at higher temperatures (dos Santos et al., 2008).

Amictic reproduction is mostly common in the spatially and temporally variable environments (Townsend et al., 2003) thus conforming well to the large proportions of species without males in variable marine habitats or in occasionally stressed habitats (Nicholas, 1975). The sex ratio in some marine forms lean towards femaleness to reproduce more in order to sustain in the unstable environment. The changes in growth rate as well as the duration of life cycle are further indicative of the volatility of environment (Palacin et al., 1993).

The fresh water species inhabiting shallow water bodies or those subject to repeated drying and wetting, tend to be without males (Grootaert, 1976; Wharton, 1986; Ocaña, 1991a) thus opting for parthenogenesis e.g., *Eumonhystera* Andrássy, 1981; *Plectus* Bastian, 1865; *Rhabdolaimus* de Man, 1880. Organisms living in isolated and unstable habitats have evolved cryptobiosis, self-fertilization, and passive dispersal, benefiting them in the challenging conditions.

Life cycle stages often provide a means of surviving changes in the environment. The laid eggs, with their sticky/complex rugose/spinose shell (Figs. 90, 91) surface, adhere to sediment particles. The eggs may further be provided with entangling devices such as byssi or polar filaments to resist water current in fresh water habitats. Experimentally a 5°C increase in temperature produces up to a six-fold increase in the number of eggs laid (Warwick, 1981c). The sperms of some aquatic nematodes may possess a pseudoflagellum (a protoplasmic hair) unlike the typically round or amoeboid (crawling) sperms of terrestrial forms. Retention of the nuclear envelope in mature spermatozoa has also been reported (Lee, 2002). One unique feature found in some marine species is traumatic insemination (Maertens & Coomans, 1979; Chabaud et al., 1983; Coomans et al., 1988), a type of copulation not occurring through vulva, but through puncturing of the cuticle followed by the formation of terminal ducts as a part of the demanian system. The excess sperms are thus discharged into the intestine (Coomans et al., 1988).

The aquatic habitats with high wave action also led to conditions of ovoviviparity in nematodes. *Monhystera paludicola* de Man, 1880 shows intrauterine hatching thus avoiding the risk of loosing the eggs in fast-flowing waters (Hofmanner, 1913; Hofmanner & Menzel, 1915; Juget, 1967). Although facultative ovoviviparity has been also observed in the shallow water populations, this characteristic was frequently expressed in toxic environments (Van Gaever et al., 2006). Some species of *Monhystera* are characterised by a specialized uterus with associated cells and glands (Figs. 88, 89) and a spermatheca.

The uterus is elongated and its length increases with age (Jacobs & Heyns, 1990) so as to hold and protect greater number of developing juveniles in stressed conditions (Otto, 1936; Schiemer et al., 1969; Otto & Schiemer et al., 1973). The highly indeterminate mode of cell division (Justine, 2002) in some aquatic enoplids contrary to normal determinate/ mosaic cell division tends to regulate the development in stressed environments.

In some marine nematodes, such as *Pellioditis marina* the cell lineage with polyclonal cell fate distribution allows a faster embryonic development by reducing the need for cell migrations (Houthoofd et al., 2003) resulting in extremely short generation time (Moens et al., 1996). Many small species have short generation times of usually about one month or less (Gerlach, 1971; Heip et al., 1985). However, the period of development varies from 3 days in Rhabditidae to 12 months in some Chromadoridae and Enoplidae (Houthoofd et al., 2003). Faster development shortens the vulnerable period of embryo to disturbances thus preventing embryonic deformities and/or arrest. Nevertheless, the generation time and fecundity are markedly temperature dependent.

Another aquatic bacterivore *Rhabdolaimus* is stated to survive as dauer stage in warm dry and acidic soils (Dmowska, 2000; Beier & Traunspurger, 2001). It has been reported that marine nematodes from oligotrophic regions of ocean are smaller in size than those from sites showing higher level of organic matter flux (Udalov et al., 2005). Such smaller nematodes produce fewer eggs than larger nematodes.

This leads to the lower rate of reproduction and therefore, to the lower proportion of juveniles. The "male: female" ratio tends to be 0.7 while a ratio of 0.4–0.6 has been found in nematode communities from deep-sea hydrothermal vents (Zekely et al., 2006).

Ecological adaptations

Light reaches only in the upper layers of the water column; hence photosynthesis is limited to a few 100 meters water depth. The main energy source for deep bottom dwellers, therefore, comes from the primary production at the surface. The organisms inhabiting this niche are mostly extremophiles, tolerant of extremely low temperatures (<0°C) and have an adaptation to high pressure as well. Aquatic nematodes, like their terrestrial counterparts, serve as food for small invertebrates or fungi and can be categorized as herbivores, carnivores, omnivores, predators, bacterivores and fungivores with a range of food sources viz., algae, diatoms, aquatic vegetation, bacteria, fungi, other small invertebrates including nematodes.

Littoral macrophytes, their associated periphytons and free-floating biofilms also provide limited in situ resources for nematodes (Peters & Traunspurger, 2005). The nature of the organic substrate in the environment changes with time. Different food supplies influence species compositions and their succession (Ferris & Matute, 2003; Ruess, 2003; Ruess & Ferris, 2004; Michiels & Traunspurger, 2005; Ferris & Bongers, 2006) directly as well as indirectly.

During the settling of food resources from surface to deep floor, much of the photosynthetic derived material is mineralized. Larval forms of soft-bodied marine invertebrates including nematodes are adapted to take advantage (Manahan, 1990) of the organic carbon as dissolved organic material (DOM). In marine environments, the meiofauna builds the trophic linkage between bacteria and macrobenthos (Kuipers et al., 1981) and constitute an energy sink (McIntyre, 1969).

Besides the direct consumption of detritus, nematodes carry out double remineralization and cycle in carbon twenty times their mass annually (Platt & Warwick, 1980). Thus nematodes facilitate the detrital conversion by mechanical breakdown of the detritus, excretion of limiting nutrients to bacteria, producing films conducive to bacterial growth and by bioturbating sediments around detritus (Riemann & Schrage, 1978; Meadows & Tufail, 1986) hence increasing porosity and light penetration. Thus the meiofaunal nematodes affect mat communities through bioturbation and grazing (Höckelmann et al., 2004).

The habitat preference has been observed in some marine nematode families (Tietjen, 1977) e.g., muds: Comesomatidae, Linhomoeidae; muddy sands: Comesomatidae, Monhysteridae, Desmodoridae, Linhomoeidae; fine sands: Monhysteridae, Comesomatidae, Desmodoridae, Axonolaimidae; medium-coarse sands: Monhysteridae, Desmodoridae, Chromadoridae; clean, coarse sands: Epsilonematidae and families of Draconematoidea. Current transport apparently plays a significant role in the dispersal of certain meiobenthic nematodes.

However, the nematodes occurring in the surficial layers of the sediments seem to be the most affected (Witthöft-Mühlmann et al., 2007). Some species like *Sabatieria pukhra* (Schneider, 1906) and *Odontophora setosa* (Allgen, 1929) found in the deeper sediment layers are rarely suspended (Eskin & Palmer, 1985). The species diversity and the occurrence of the nematodes are influenced mainly by wind speed and river discharge. In calm weather and low discharge, species diversity is reduced and deposit feeders dominate.

The feeding habits can be inferred from the physiognomic characters of buccal cavities (Wieser, 1960; Wieser & Kanwisher, 1961; Boucher, 1973; Platt, 1977; Romeyn & Bouwman, 1983; Jensen, 1987b) and associated structures (Bouwman et al., 1984) in aquatic species. The epistrate feeders e.g., *Eudiplogaster paramatus* (Schneider, 1938); *Chromadorita tenuis* (Schneider, 1906) etc. are toothless or possess a small tooth in buccal cavity to break open cell membranes and suck out the cell contents (juice feeders); deposit feeders (particulate feeders) with or without tooth, swallow the whole food item and prevent its escape e.g., *Daptonema biggi* (Gerlach, 1965) Lorenzen, 1977 (swallowing diatoms), *Linhomoeus gittingsi* Jensen, 1986 (engulfing sulphide-oxidising bacteria.

Sediments with high silt content generally show abundance of deposit-feeders (Heip et al., 1985) usually scoring 2 or 3 on the coloniser-persister scale (Bongers et al., 1991, 1995), characterised by short life cycles and a high colonisation ability (Schratzberger et al., 2007). Predators with buccal cavities armed with movable/protrusible mandibles
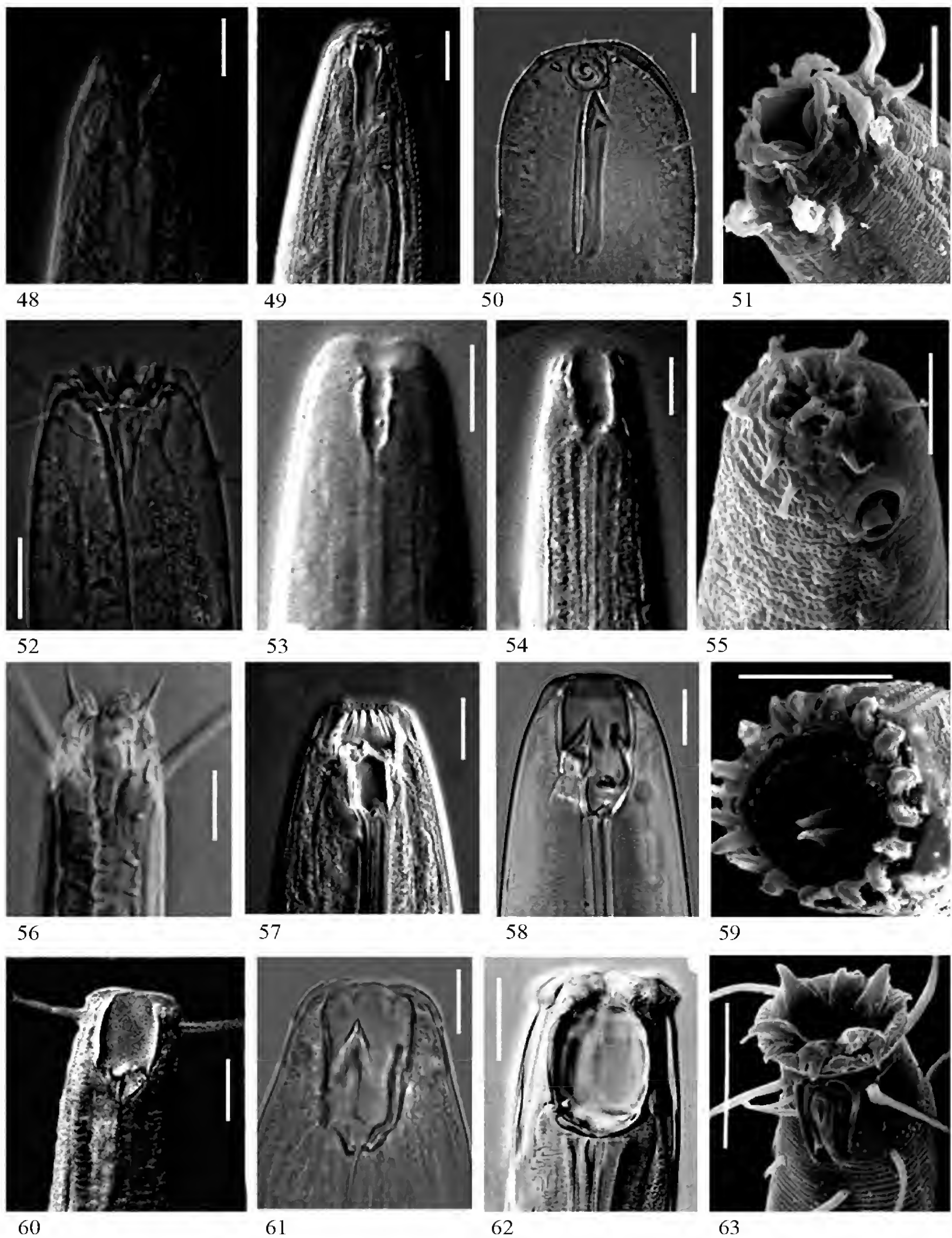
Figures 48-63. Modifications in stoma.
Fig. 48: *Bujaurdia* sp. Fig. 49: *Plectus* sp. Fig. 50: *Onyx* sp. Fig. 51: *Tripylina* sp. Fig. 52: *Odontophora* sp. Fig. 53: *Udonchus* sp. Fig. 54: *Diplogastrellus* sp. Fig. 55: *Achromadora* sp. Fig. 56: *Enoplolaimus* sp. Fig. 57: *Mononchoides* sp. Fig. 58: *Odontopharynx* sp. Fig. 59: *Fictor* sp. Fig. 60: *Prismatolaimus* sp.; Fig. 61: *Onchulus* sp. Fig. 62: *Iotonchus* sp. Fig. 63: *Odontophora* sp. www.nem.wur.nl/UK/In+the+picture/Gallery/ (Scale bar = 10 μm).
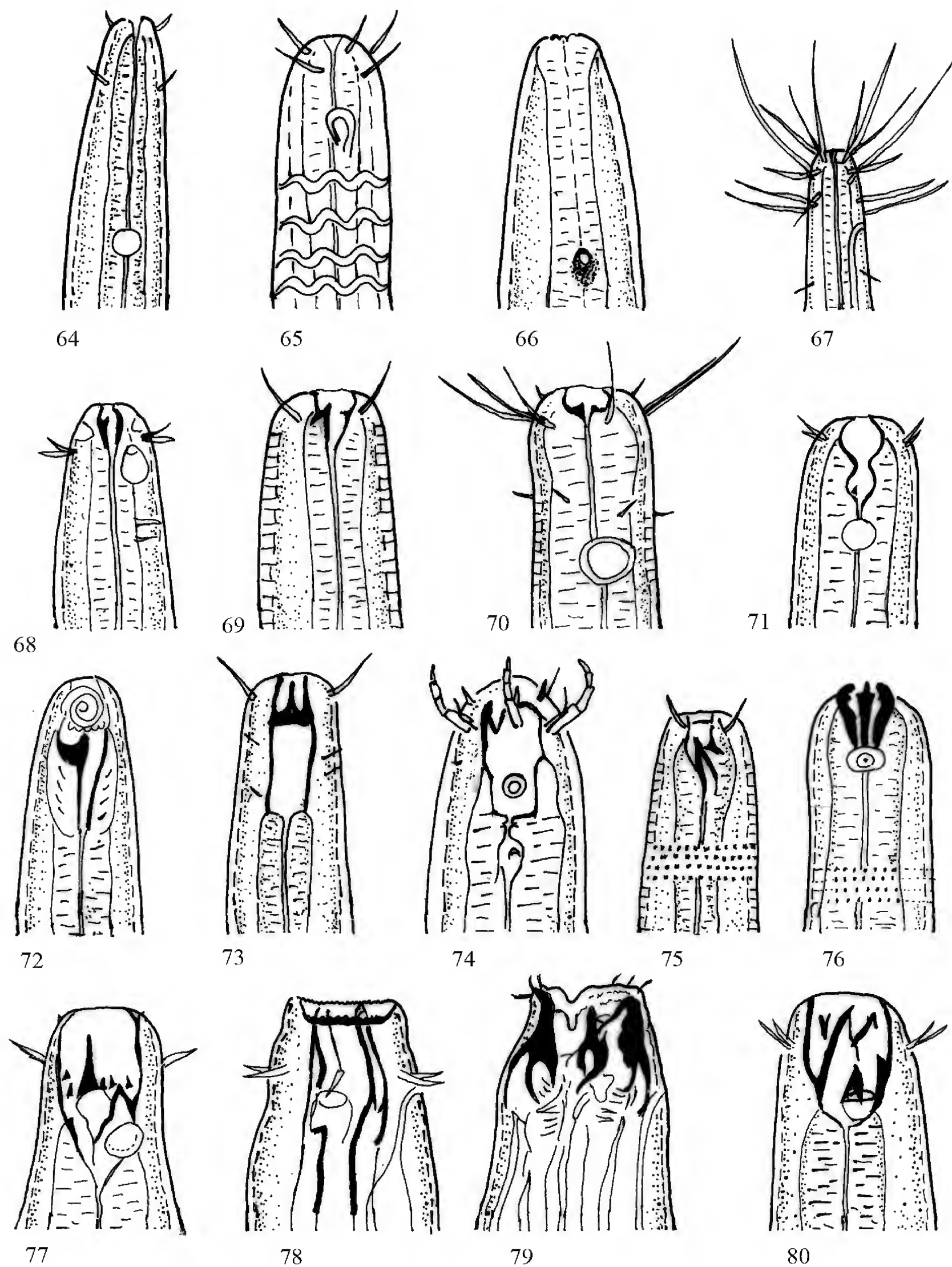
Figures 64-80. Modifications in stoma.
Fig. 64: *Oxystomina* sp. Fig. 65: *Ceramonema* sp. Fig. 66: *Pseudocella* sp. Fig. 67: *Barbonema* sp. Fig. 68: *Odontanti-coma* sp. Fig. 69: *Neochromadora* sp. Fig. 70: *Cobbia* sp. Fig. 71: *Gammarinema* sp. Fig. 72: *Gomphionema* sp. Fig. 73: *Parodontophora* sp. Fig. 74: *Bathylaimus* sp. Fig. 75: *Ptycholaimellus* sp. Fig. 76: *Synonchium* sp. Fig. 77: *Octonchus* sp. Fig. 78: *Calyptronema* sp. Fig. 79: *Filipjevia* sp. Fig. 80: *Ditlevsenella* sp.

for swallowing the whole prey (e.g., members of Thoracostomopsidae, Enoplidae, Selachinematidae) can be largely classified as persisters; and the scavengers with buccal cavity provided with a lumened onchium (tooth-like structure) to feed on dead animals or suck the cell contents of injured animals e.g., oncholaimids and enchelidiids.

Bonger's (1990) colonizer-persister classification of nematodes holds good for terrestrial and freshwater habitats, however, it has less application in marine habitat (Bongers et al., 1991; Fraschetti et al., 2006), partly due to a lack of empirical support for the classification of some marine genera and the absence of extreme colonisers and persisters in most marine habitats. Nevertheless, *Sabatieria* has been found to be a good colonizer showing dominance in anthropogenically disturbed sediments (Tietjen, 1980).

The individuals have evolved life-history characteristics (e.g. rapid growth rate, ability to adapt to a wide range of environmental conditions) that allow them to quickly establish in newly exposed habitats or disturbed sediments in high densities (Thistle, 1981; Moore & Bett, 1989; Somerfield et al., 1995). The environmental constraints restrict species establishment and mediate interactions between successful colonists (Schratzberger et al., 2008) *Leptolaimus* de Man, 1876 found at physically disturbed sites, is not classified as truly opportunistic species (Modig & Ólafsson, 1998).

Ullberg & Ólafsson (2003) hypothesised that the agility of such small, surface-dwelling nematode species with high dispersal potential (Lee et al., 2001; Commito & Tita, 2002) might be an evolutionary response towards higher levels of competence for coping with disturbance (Schratzberger et al., 2009).

Adaptations to stress

Many aquatic nematodes can adapt physiologically to environmental challenges (Samoiloff et al., 1980, 1983; Mutwakil et al., 1997; Doroszuk et al., 2006). Fresh water as well as deep sea environments offer much hostile and extreme conditions compared to other aquatic habitat types. Therefore, the physiological challenges faced by nematodes are greater in these ecosystems.

A variety of environmental stresses may trigger quiescence viz., desiccation or high temperature (anhydrobiosis), low temperature (cryobiosis), osmotic stress (osmobiosis) and low oxygen (ano-xybiosis); in extreme cases of prolonged quiescence, the metabolic rate may fall below detectable levels and appear to cease. This extreme dormant condition is referred to as anabiosis (Wharton, 1986) or alternatively as cryptobiosis (Cooper & van Gundy, 1971). Unlike diapause, the dormant state ends when the environmental stress is relieved.

Temperature. Many biological structures, such as enzymes and lipid bilayer membranes may show molecular instability or fluidity due to temperature extremes. Increasing temperatures can increase reaction rates and can cause protein denaturation, resulting in complete and often irreversible loss of function (Hochachka & Somero, 1984). In fresh water ecosystems such as springs, nematodes generally tend to avoid high temperatures above 43°C and high ionic concentrations (Ocana, 1991a, b) except *Rhabditis terrestris* (Stephenson, 1942). At hydrothermal vents, however, temperature can range from 2°C to 400°C and animals may have occasional brief contact with temperature difference of 100°C (Chevaldonné et al., 1992; Delaney et al., 1992; Cary et al., 1998; Desbruyères et al., 1998).

The deep sea is a relatively inhospitable environment for metazoans with constantly low (~2 °C) ambient temperature, high pressure, absence of light and scarce organic carbon. Adaptation to the deep sea includes presence of more "fluid" proteins and lipids to counter the high pressure and low temperature (Hochachka & Somero, 1984). Low temperatures may slow or impede many biochemical reactions and decrease the fluidity of lipids, a factor of primary importance to cell membrane function (McMullin et al., 2000).

Most of the adaptations that enable polar intertidal invertebrates to survive freezing, are associated with their ability to withstand aerial exposure. Nematodes surviving the freezing, exhibit low metabolic rate and slow growth rate and the inability to survive at temperatures above 3-8°C. The bacterial-feeder, *Plectus murrayi* Yeates, 1970 (Timm, 1971) inhabiting semi-aquatic and terrestrial biotopes in the Antarctic McMurdo Dry Valleys, has its distribution limited by organic carbon and soil moisture and survives extreme desiccation, freezing conditions, and other types of stresses (Adhikari et al., 2010).

The Antarctic nematode, *Panagrolaimus davidi* Timm, 1971 shows both freeze-avoidance and freeze-tolerance strategies thus experiencing freezing temperatures over nine months of the year and

facing regular cycles of freezing and thawing in spring; the nematode thus undergoes cryoprotective dehydration instead of freezing when held at its nucleation temperature for a longer period, or when cooled at a slower rate (Wharton et al., 2003).

P. davidi is the only animal known to survive ice crystallization within its cells (Wharton et al., 2005). With slower cooling rates, the water inside the worm is super cooled, thereby creating a vapor pressure difference between the ice in the medium and the nematode. Besides synthesizing trehalose, *P. davidi* produces a protein that inhibits the activity of organic ice nucleators though the sequence of this protein has no homology with any other anti-freeze or ice-nucleating proteins (Wharton et al., 2005).

Oxygen. Many meiobenthic species persist over extensive periods under hypoxic and anoxic conditions (Wetzel et al., 2002). Nematodes are the most tolerant organisms as their species richness does not change in hypoxic-anoxic conditions though their species composition and trophic structure display significant changes (Gambi et al., 2009).

Jensen (1987a) found that species, living in deeper sediment layers were significantly more slender than their oxybiotic, surface-dwelling congeners, however, nematodes of the genera *Desmoscolex* Claparède, 1863; *Tricoma* Cobb, 1894 and *Cobbionema* Filipjev, 1922 have been reported mostly from the anoxic depths (> 300 m) of the Black Sea (Zaitsev et al., 1987). At some places even *Desmoscolex* and *Bolbolaimus* Cobb, 1920 are replaced by the species (*Chromadorella* Filipjev, 1918, *Sabatiera* Rouville 1903 and *Polysigma* Cobb 1920) more tolerant to the extreme conditions (Gambi et al., 2009).

Oxygen stress is successfully tackled by the fresh water genera of Monhysteridae and Tobrilidae (Triplonchida) having prevalence in the habitats with limited or no oxygen (Nuss, 1984; Jacobs, 1987). Low oxygen concentrations are tolerated well by most *Rhabditida* (Ocana, 1993). Such species survive anaerobic sediments by anaerobic metabolism, facultative anaerobic metabolism or quiescence (Bryant et al., 1983). Few species can cope with changing oxygen levels by alternating between aerobic and anaerobic metabolism similar to the mechanism found in the insect parasite *Steinernema carpocapsae* Weiser, 1955 (Shih et al., 1996).

Likewise a species *Allodorylaimus andrassyi* (Meyl, 1955) Andrássy, 1986 (Dorylaimida) found to survive in oxygen-free sediments of Lake Tiberias (Israel) for 8 months of a year (Por & Masry, 1968). High salinity and high temperature are less common physiological stresses for aquatic nematodes than low oxygen. In springs, *Udonchus* Cobb, 1913 and *Rhabdolaimus* have been reported to tolerate high salinity and temperature (Ocaña, 1991a, b). However, the genus *Mesodorylaimus macrospiculum* Zullini, 1988 seems to withstand stress (Tudorancea & Zullini, 1989) in intermittent lakes that are subject to high salinity and temperature.

The ability to survive under anaerobic conditions may thus be quite widespread among nematodes, although different mechanisms may be involved (Schiemer & Duncan, 1974; Bryant et al., 1983). The presence of *Theristus anoxybioticus* Jensen, 1995 at the oxygenated sediment surface of muddy sediment suggested that even this facultative anaerobe nematode needs to reach oxygen for its reproduction (Jensen, 1995).

Thus, survival under anoxia would be possible only under critical conditions. For reproduction on the other hand, especially for the development of eggs, there must be another more efficient pathway of energy production (Riess et al., 1999) although nitrate respiration has never been reported in nematodes so far.

In shallow beaches drifting macroalgal mats in the summer months induce anoxic and sulfidic conditions with devastating effects on members of the benthic fauna. Other disturbances like eutrophication in conjunction with density-stratified water masses frequently results in severe oxygen depletion of bottom waters, especially during the summer months, leading to hypoxic (dissolved oxygen concentration <2 mg l^{-1}) or even anoxic (dissolved oxygen concentration of 0 mg l^{-1}) conditions (Rosenberg et al., 1992). While most hypoxic events affect the fauna in deeper sublittoral regions below a thermo- or halocline; eutrophication has also been attributed to the increase in benthic macroalgae (Rosenberg, 1985; Hull, 1987; Raffaelli et al., 1991; Kolbe et al., 1995).

There is induction of Hb synthesis in many invertebrates under stressful conditions (hypoxia, temperature increase and CO poisoning). The mud-dwelling nematode *Enoplus brevis* Bastian, 1865 with a pharyngeal haemoglobin (Hb) shows feeding rates under hypoxia than the related, *E. communis* Bastian, 1865 that lacks Hb (Atkinson, 1977). Hb may be associated with vital functions in euryhaline invertebrates living in widely different salinities and pH and lacking significant osmotic, ionic, and acid-base regulatory capacities (Weber & Vinogradov, 2001).
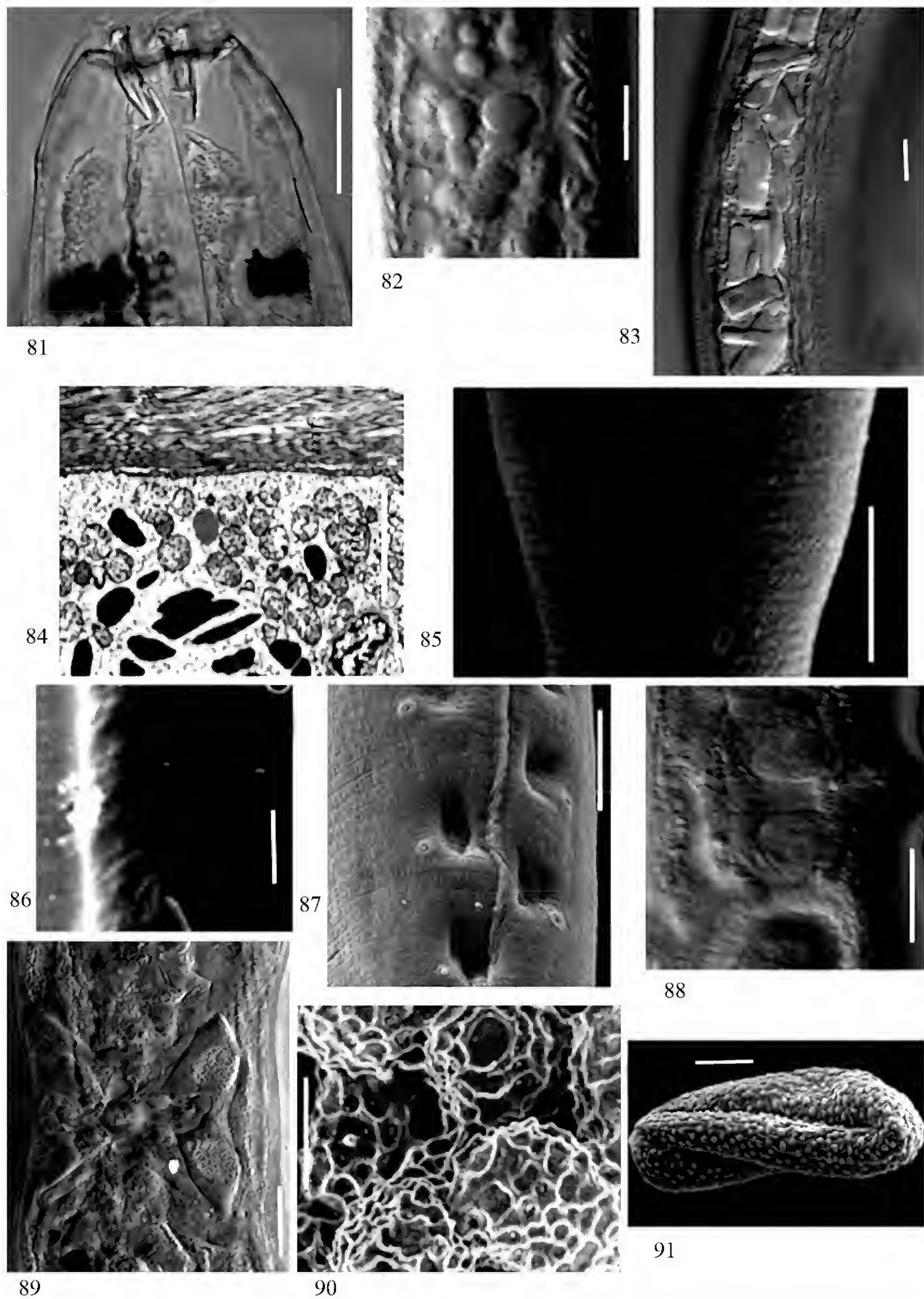
Figures 81-91. Fig. 81: Pigment spot in *Enoplus* sp. Fig. 82, 83: Crystalloids in pseudocoelom of *Tobrilus* sp. and *Ironus* sp. Fig. 84: Ultra structure showing longitudinal section of muscle fibres with crystalloids and electron-dense bodies. Fig. 85, 86: Body pores in *Cryptonchus* sp. and *Ptycholaimellus* sp. Fig. 87: Hypodermal gland openings. Fig. 88, 89: glands associated with uterus and vagina. Fig. 90, 91: Egg shells with rugose or spinose surface
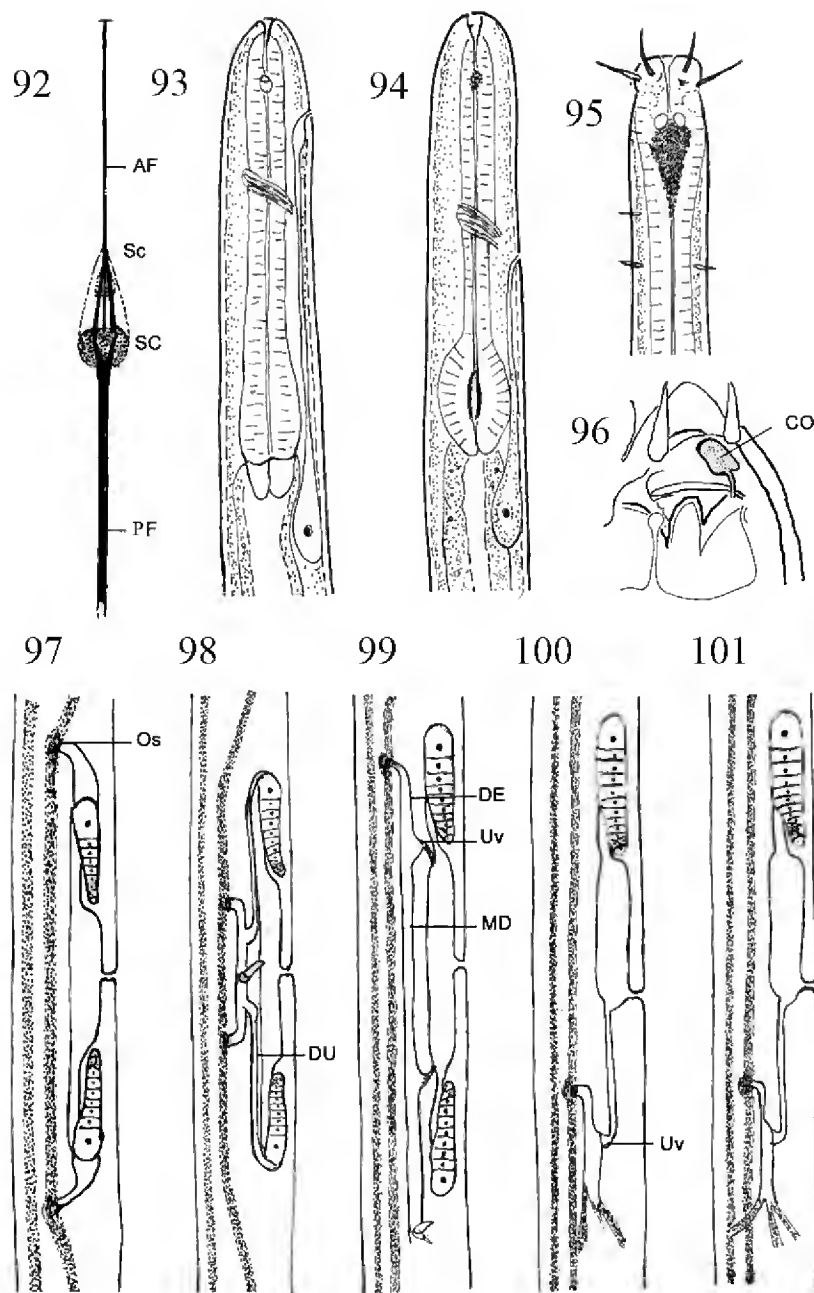[Scale bar: 81-83, 85-89, 90, 91 = 10 μm; 84 = 1 μm).

Figure 92: Metaneme (AF: anterior filament, PF: posterior filament, Sc: Scapulus, SC: sensory cell). Fig. 93: pigment spot. Fig. 94: Ocellus. Fig. 95: Ocellus surrounded by pigments. Fig. 96: Anterior end of nematode with cephalic organ (CO). Figures 97-101: Demanian system (Os: Osmosium; Uv: Uvette; MD: Main duct; DE: Ductus entericus; DU: Ductus uterinus).

Water. The aquatic nematodes face two basic problems of water gain or water loss depending upon the type of surrounding environment.

Marine nematodes the osmoconformers, often live in water that has a very stable composition and, hence, they have a very constant internal osmolarity. Many invertebrates that osmoconform achieve tissue tolerance by increasing intracellular osmolarity by mobilization of amino acids, thereby balancing extracellular fluid.

This reduces the osmotic gradient across cell membranes and maintains constant cell volume (Schmidt-Nielsen, 1997; Kirk et al., 2002).

Panagrolaimus davidi, an Antarctic nematode, is associated with ornithogenic soils (Porazinska et al., 2002) in coastal areas that are ice-free during spring and summer with sufficient meltwater from adjacent snowbanks. The water content of these sites varies from saturated to completely dry (Wharton, 1998) and the nematode faces changes in external osmotic concentration (Wharton, 2003). *Panagrolaimus davidi* maintains its internal osmotic concentration above that of the external medium and is thus an hyperosmotic regulator.

The nematode achieves regulation under hyposmotic stress more rapidly than under hyperosmotic stress (Wharton, 2010). The nematodes found in coastal zones are exposed to conditions of rapid de- and rehydration similar to the mosses and lichens. Drying initially decreases rates of anaerobic microbial processes in sediments due to reduced oxygen penetration (Baldwin & Mitchell, 2000). Differences among aquatic and terrestrial species in resistance to desiccation and inundation cause shifts in community composition along hydro-period gradients (Larned et al., 2007).

The ability to enter anhydrobiosis may be one of the most important and widespread adaptations in evolutionary terms amongst nematodes but not expressed in species of stable habitats. Freshwater nematodes of temporary ponds commonly enter quiescence in response to water stress (Wharton, 1986; Womersley & Ching, 1989). The phenomenon is also common in nematodes of polar regions (Pickup & Rothery, 1991; Wharton & Barclay, 1993; Wharton, 2004). Important information on anhydrobiosis has been provided by several workers (Cooper & van Gundy, 1971; Demeure & Freckman, 1981; Wharton, 1986; Womersley, 1987; Barrett, 1991; McSorley, 2003).

The onset of anhydrobiosis marks a gradual water loss from 75-80% to 2-5% in anhydrobiotic forms (Demeure & Freckman, 1981). The fresh water nematodes *Actinolaimus hintoni* Lee 1961 and *Dorylaimus keilini* Lee, 1961 were revived from cryptobiotic (anabiotic) stage in dried mud (Lee, 1961).

Anhydrobiotic nematodes contain large amounts of sugars, especially the disaccharide trehalose, a dimer of glucose that protects cells by replacing water associated with membranes and proteins.

However, most species are killed if drying occurs too quickly whereas repeated events of drying and rehydration decrease viability of nematodes (Demeure & Freckman, 1981; Barrett, 1991). Anhydrobiotic nematodes rehydrate in water, but there is an average lag time (from less than an hour to several days) between immersion and their return to

normal activity (Cooper & Van Gundy, 1971; Wharton, 1986; Barrett, 1991). Recovery is improved if rehydration is slow, and nematodes are exposed to high relative humidity before being immersed in water. Anhydrobiosis involves decreased cuticular permeability and the condensation or packing together of tissues with increased levels of trehalose or glycerol (Demeure & Freckman, 1981; Wharton, 1986; Womersley, 1987; Barrett, 1991). Coiling is a typical behavioral response observed in anhydrobiotic nematodes.

Pollutants. Environmental pollution is an important cause of stress in natural populations. Besides affecting the population dynamics, it can also lead to genetic changes (mutations) and adaptations. The nematode bioassays lead to detection of a wide range of chemical concentrations with distinct toxic effects of lethality, developmental inhibition and mutagenicity. Most studies have been undertaken using the continental species *Panagrellus redivivus* Goodey, 1945 against few studies carried out on aquatic nematodes to determine pollution and toxicity in marine environments (Warwick, 1981b; Samoiloff & Wells, 1984; Bogaert et al., 1984; Vranken et al., 1991).

Aller & Aller (1992) showed that meiofauna activity stimulated solute fluxes and reaction rates, particularly aerobic decomposition and associated processes such as nitrification in the oxic zone of the marine sediments. Among toxicants, sulfide is perhaps the most abundant with its impacts on biological systems well documented (Somero et al., 1989; Grieshaber & Völkel, 1998).

Sulfide, in just micromolar amounts, is capable of impairing biological processes and may severely inhibit aerobic metabolism by interfering with cellular respiration and oxygen transport in different metazoan (Somero et al., 1989; Vismann, 1991; Grieshaber & Völkel, 1998; Szabó, 2007). In the mitochondria, sulfide may poison the respiratory enzyme cytochrome c oxidase, thus inhibiting ATP production by the electron transport chain and is capable of inhibiting muscular contraction independent of its effects on aerobic metabolism (Julian et al., 1998).

Thus an organism adopts the strategies to avoid sulfide, switch to anaerobic metabolism (Grieshaber & Völkel, 1998), exclude sulfide from sensitive tissues, or oxidize sulfide to less toxic forms. Most inhabitants of vent and seep environments do not realistically have the option of avoiding sulfide

altogether. Some marine nematodes e.g., *Oncholaimus campylocercoides* De Coninck & Stekhoven, 1933; *Sabatieria wieseri* Platt, 1985; *Terschellingia longicaudata* de Man, 1907; *Sphaerolaimus papillatus* Kreis, 1929; *Siphonolaimus ewensis* Warwick & Platt, 1973; *Pontonema vulgare* Bastian, 1865, while living in sulphidic transition zones convert hydrogen sulphide to elemental sulphur which temporarily reduces the concentration and toxic effect of H_2S and also provides an energetic 'deposit' for latter oxidation to thiosulphate, sulphite or sulphate under oxic conditions (Thiermann et al., 2000).

Many nematodes (Stilbonematinae, Desmodoridae) harbour symbiont chemoautotrophic bacteria (Hentschel et al., 2000; Ott et al., 2008; Bayer et al., 2009) that oxidize sulfide and fix CO_2. The Hbs of these organisms bind sulfide without covalent modification of the heme groups and facilitates its transport or diffusion thus protecting the tissues from sulfide poisoning.

These symbionts, in turn, constitute the worms' major food source and are acquired from the environment and shed off at every moult but reacquired from the environment. The mechanisms of symbiont recruitment from the environment (Bulgheresi et al., 2006) have shown that Ca_2^+-dependent lectin Mermaid mediates symbiont–symbiont and worm–symbiont attachment in *Laxus oneistus* (Ott et al., 1995).

Thick tubes or cuticles reduce or prevent exposure of some external tissues to sulfide with *Ptycholaimellus* serving a good example (Nehring et al., 1990). The effect of mercury contamination was rather confusing as low doses of mercury appeared to have much more drastic effects than the medium and high doses.

Austen and McEvoy (1997) observed that low doses of copper and zinc seem too toxic to kill all the bacteria and meiofauna in the samples so that complete decomposition of nematodes did not occur (Hermi et al., 2009). Schratzberger et al. (2009) found *Araeolaimus bioculatus* (de Man, 1876) to be intolerant to mercury contamination, with effects observed even at the low concentration used (0.084 ppm dw).

Marylynnia stekhoveni (Wieser, 1954) was categorized as "opportunistic" at low and medium mercury doses with Hg(L) and Hg(M) concentrations whereas *Prochromadorella neapolitana* (de Man, 1876) Micoletzky, 1924 was found to be a "mercury-resistant" species (Schratzberger et al., 2009).

Pollutants also modify the distribution and abundances of nematodes through indirect ecological interactions (Johnston & Keough, 2003). If pollution decreases abundance of a competitively dominant species, inferior competitors may increase in abundance not as a direct result of the contaminant but due to altered competition. Copper causes decrease in recruitment and abundance of a number of organisms (Johnston & Keough, 2000, 2003; Mayer-Pinto et al., 2010). Thus metazoans largely detoxify absorbed or ingested metals by using metal-binding proteins (metallothioneins) and forming subcellular inclusions.

These mechanisms often act jointly to consolidate and enclose excess metals, which then accumulate within tissues and/or skeletal structures over time (Beeby, 1991; Luoma & Carter, 1991). The metal detoxification strategies used by nematodes are not very different from those used by other organisms (McMullin et al., 2000) for example the existence of phytochelatins, the heavy metal-binding peptides, in nematodes that are synthesized by plants and fungi when exposed to metals (Monserrat et al., 2003).

Phylogenetic implications

Assuming that all life originated in the sea and that metazoan phyla evolved more than 550 million years ago (mya) during the Precambrian period (Conway, 1993; Valentine et al., 1996, 1999; Fedonkin & Waggoner, 1997; Peterson & Davidson, 2000), it can be assumed that the ancestral nematode was also marine.

Nematodes also lack an informative fossil record (the oldest known fossil, *Cretacimermis libani* Poinar et al., 1994 (Poinar, 2003) dates to around 135 mya). Filipjev (1929, 1934) and Lambshead & Schalk (2001) have accepted the marine ancestry of Nematoda while De Ley & Blaxter (2002, 2004) considered a terrestrial origin for the Nematoda.

As highly productive terrestrial ecosystems existed in the Precambrian there might have been chances of supporting the evolution of a new phylum (Kenny & Knauth, 2001). Nevertheless, a marine origin of the Nematoda can be traced as some terrestrial taxa of current phylogeny have been found nested within marine clades.

The strongest evidence for a marine ancestry of the Nematoda comes from the Chromadorea: the basal clades are all predominantly marine (Micro-laimoidea, Chromadorida, Desmodorida, Monhysterida, and Araeolaimida) whereas the almost exclusively non-marine *Rhabditida* are derived from the ancestor of the Monhysterida or Araeolaimida (Meldal et al., 2007).

The similarity in cuticular structure of *Acanthonchus* Cobb, 1920 (Wright & Hope, 1968), *Chromadorina* Filipjev, 1918 (Lippens, 1974), and *Caenorhabditis* (Epstein et al., 1971; Zuckerman et al., 1973) lends circumstantial evidence to the hypothesis that the Secernentea arose from chromadorid-like ancestors. However, a reinterpretation of the cuticular structure by Decraemer et al. (2003) suggested that this is a homoplasic character that has appeared independently in several clades.

Though aquatic nematodes can not be treated separately as far as the phylogenetic grouping is concerned. Nevertheless, one of these lineages includes marine, freshwater and terrestrial taxa, suggesting that early *Enoplia* were characterised by much greater osmotic tolerance than early *Dorylaimia* (De Ley, 2006).

Most enoplids include large predators with big hooks or teeth in more or less complex arrangements as well as some additional sensory structures such as eyespots and the stretch receptors (metanemes). They are interesting phylogenetically because of possessing some features, presumably ancestral within Nematoda viz., a highly indeterminate mode of development (Justine, 2002) and retention of the nuclear envelope in mature spermatozoa (Lee, 2002).

The ventrally spiral amphid was considered plesiomorhic by Lorenzen (1981), yet the non-spiral form seemed to be a secondary character loss. Likewise, the presence of ocelli is usually considered to be a primitive character though these structures are the most complex photoreceptors that the nematodes possess.

Coomans (1979) suggested that the pigment spots and their associated amphidial photoreceptors are less elaborate and may represent a stage that originated later in the evolution and so have not yet achieved great complexity.

Nevertheless, the occurrence in nematodes with both types of photoreceptors: rhabdomeric and ciliary, supports Vanfleteren & Coomans's (1976) and Sharma et al.'s (2006) conclusion that morphological characters used in the classification are not enough to recognize phyla along the main lines of evolution.
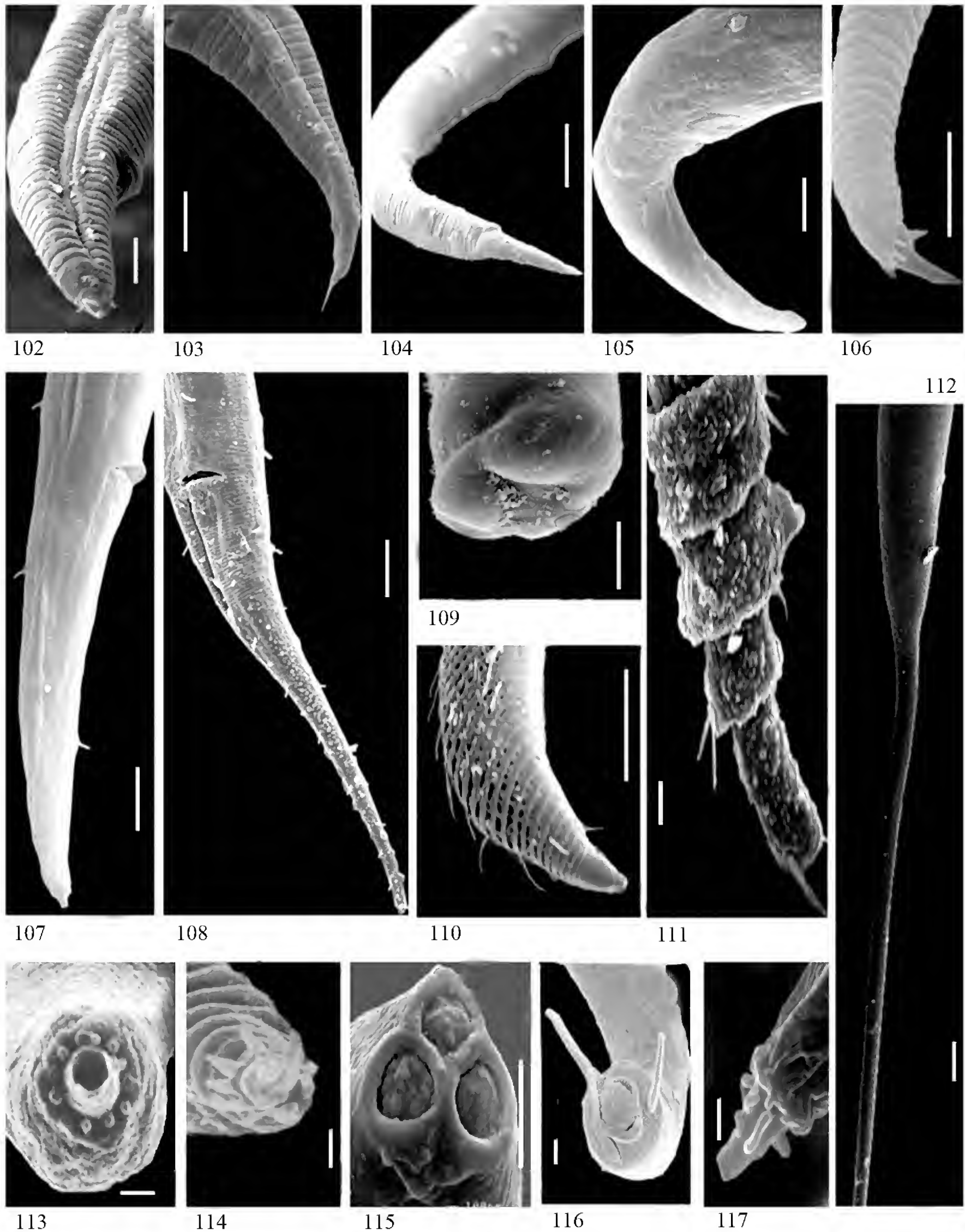
Figures 102-112. Modifications at posterior body end.
Fig. 102: *Anaplectus* sp. Fig. 103: *Panagrellus* sp. Fig. 104: *Rhabdolaimus* sp. Fig. 105: *Tripylina* sp. Fig. 106: *Chronogaster* sp. Fig. 107: *Plectus* sp.; Fig. 108: *Tobrilus* sp. Fig. 109: *Philometra* sp. Fig. 110: *Epsilonema pustulatum* after Karssen et al., 2000. Fig. 111: *Desmoscolex* sp. Fig. 112: *Cryptonchus* sp. Figures 113-117. Modifications at tail terminus. Fig. 113: *Plectus* sp. Fig. 114: *Chronogaster* sp. Fig. 115: *Epsilonema pustulatum* after Karssen et al., 2000. Fig. 116: *Dorylaimopsis variabilis* Muthumbi et al., 1997. Fig. 117: *Tobrilus* sp. (Scale bar: 102-112 = 10 µm; 113-117 = 1 µm).

CONCLUSION

Aquatic nematodes are of vital importance as a very significant portion of the energy flow in the benthic system passes through these nematodes. However, one of the main reasons for the aquatic nematodes being ignored is that they are not of direct benefit or nuisance to man. Their role in stimulating bacterial metabolism is now well documented (Tenore et al., 1977; Tietjen, 1980) and they have an important and direct influence on the productivity of shallow waters by enhancing nutrient regeneration in the sediments.

They also affect the texture (Cullen, 1973) and the physical characteristics of sediments by mucous secretion, which are significant for dredging and dumping operations. It can be further said that the story of their adaptations to a particular environment type is far more complex than could be inferred. Despite the recent information gained, studies are required on the plesiomorphous forms, the mutants and the apomorphs to reveal how far deviations exist.

Future researches should further consider the detailed structure and anatomy of the receptors as modification in them are reflected in changes in behaviour. Although the nematode nervous system is considered to be a conservative system with a rather small number of cells, different behavioural patterns exist according to the different environments and ecological niches occupied by the species.

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Reproductive biology and growth of Lesser Spotted Dogfish *Scyliorhinus canicula* (Linnaeus, 1758) in Western Algerian coasts (Chondrichthyes, Scyliorhinidae)

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ABSTRACT

Elasmobranch fishes have a large distribution. At the level of the Mediterranean fisheries, a low density of elasmobranchs is noted at the assemblages, these fisheries appearing near to the point of best efficiency or even to over-exploitation. Indeed, a general decline of shark populations was observed over the last decade on the Mediterranean coast. The aim of this work was to evaluate different biological characteristics of the species *Scyliorhinus canicula* (Linnaeus, 1758). A sampling of 461 specimens was realized between September 2009 and August 2010 from the western coast of Algeria. The oviduco-somatic index OSI, the hepato-somatic index (HSI) and the condition factor (Kn) were estimated monthly for 249 females to identify the reproduction period. Obtained results show a rapid maturation from September to November and from February to April when the Kn values are very low.

INTRODUCTION

The Lesser Spotted Dogfish *Scyliorhinus canicula* (Linnaeus, 1758), a species of Chondrichthyens fish studied in several areas of the globe, oviparous, abundant and frequently observed along the coasts of Europe in the Atlantic and Mediterranean (Halit & Taşkavak, 2006), is very abundant on the Algerian coast.

Recently, *S. canicula* was shown to be a good indicator to evaluate the level of exploitation of the marine ecosystem by its vulnerability to the fishing impact due to its slow growth, late reproduction and very low fertility rates (Rodriguez-Cabello et al., 1997; Massutí & Moranta, 2003) and by its association with other noble species frequenting the same habitat.

Taking into account that length at maturity, fecundity and sex-ratio are some of the most important parameters in studying reproductive dynamics

of elasmobranch population, this study was carried out by examination of annual changes of the oviduco-somatic index (OSI), hepatosomatic index (HSI) and condition factor (Kn) in order to evaluate the level of the exploitation in the Algerian coasts.

In fact, on southern Mediterranean coast, the knowledge on *S. canicula* is still fragmentary, being limited to some remarks about Algerian waters.

Therefore, the aim of the present paper was to study the population dynamics, reproduction, condition, age and growth of this species. This is the first paper with a complete analysis of the biology of *S. canicula* in south-western Mediterranean.

MATERIAL AND METHODS

A-Reproduction study

A series of biological samples was conducted on specimens of *S. canicula* caught by the commercial

trawlers in the sampling area of Oran and Arzew (Fig.1). Specimens' total length was measured and both sex and maturity were reported for females which represent the focus of our study. Three different maturity stages were defined (Table 1) according to Rodriguez-Cabello et al. (2007) and Capapé et al. (2008).

Stage	Microscopic aspect (color and eggs' texture)
I immature	No eggs and no Capsules
II Beginning of maturation	Ovaries small, light brown, egg-capsules rigid
III Advanced maturation	Ovaries enlarged, dark brown, egg-capsules rigid

Table 1. Different stages of maturity of *Scyliorhinus canicula* females.

Sex-ratio analysis was performed studying global sex-ratio, sex-ratio by length classes and sex-ratio by seasons using the logistic model STATISTICA Software (StatSoft Inc., 2001) and calculating the heterogeneity test χ^2 with one degree of freedom, p <0.05. The value of the reduced distance (Schwartz, 1983) was also estimated; it is a homogeneity test which compares the average sizes of males and females, in case of large samples, by the following equation:

$$\varepsilon = \frac{\left|\overline{X}_1 - \overline{X}_2\right|}{\sqrt{\dfrac{\sigma_1^2}{n_1} + \dfrac{\sigma_2^2}{n_2}}}$$

With reference to the work of Capapé et al., (2008) and to define the beginning and the extent of spawning period, oviduco-somatic index (OSI) was calculated using the following equation OSI= (OW/TW)*100, where OW is capsules' weight and TW is total weight of the specimens.

Hepatosomatic index (HSI) was calculated using the following equation: HSI= (LW/TW)*100, where LW is liver weight and TW is total weight of the specimens. Variation of OSI and HSI related to sexual maturity stages and seasons was examined in *S. canicula* females.

Finally, to monitor morphological variations, the condition index was calculated to assess the degree of overweight consecutive to genital development and repletion state of the target species. Condition factor was studied in females in order to show differences of Kn (Le Cren, 1951) related to time, according to the formula: Kn = W/W_{th} with W_{th} = aL^b where "W" is the total weight, "W_{th}" is the theoretical weight, "a" and "b" are coefficients of the relative growth between weight and length and "L" is total length.

B-Growth Study

The objective of this part of the study was to define several biological characteristics, such as structure of population size, growth and age of *S. canicula* in the study area.

Basic principle of the growth equation of Von Bertalanffy.

There are several mathematical models to express the growth in elasmobranchs. A detailed review was made by Beverton & Holt (1957), Ursin (1967), Gulland (1983), Sparre & Venema (1996) and Pauly & Moreau (1997). The most popular model is Von Bertalanffy (1938) growth equation: $Lt = L\infty \left[1 - e^{-k(t-to)}\right]$.

ELEFAN method (ELECTRONIC LENGTH FRENQUENCY ANALYSIS).

In this study, we used a numerical method, the method ELEFAN (Pauly & Moreau, 1997). For mathematical modeling, the LFDA software (Kirkwood et al., 2001) was used. Analyses were made for males and females, separately.

RESULTS

A-Study of reproduction

1) Sex–ratio

After sexing of 461 specimens we found a sampling rate of 54.01% of femininity significantly more important than males sex ratio (45.99%). These results are consistent with other studies carried out in different parts of the Mediterranean at depths ranging between 200 and 500 m (Rodriguez-Cabello et al., 1998; Capapé et al., 2008) (Table 2).

The length abundance curve is shown in figure 2. Figure 3 shows a variation of the percentage of females per month. The females percentage is still dominant during the end of summer and at the beginning of autumn up to winter, declining in the spring period.

Results were compared with theoretical ε (1.96) at a rate of 95% confidence (Table 3). The calculated value of ε = 0.33 is less than the value (1.96) given by the table of the z-score; this finding indicates that males are, on average, significantly larger than females. As regards the sexual maturation of females, different stages of maturation of the gonads during different months of the year are shown in figure 4.

Sex	Total	Percentage
Females	249	54.01%
Males	212	45.99%
Total	461	* 100%

Table 2. Percentage of sexes in *Scyliorhinus canicula* (*p<0,05).

Sex	Males	Females
Total	212	249
X (cm)	37.02	35.10
σ² (cm)²	1943.02	1965.25
ε Difference	0.33 significant	

Table 3. Different size parameters of males and females of *Scyliorhinus canicula*.

2) Indices of fish condition

In our study we have used three indeces to determinate the spawning period of the species in the study area: the oviduco-somatic index (OSI) specific to Elasmobranchs, hepatosomatic index (HSI) and condition index (Kn). These allowed to quantify morphological changes of the specimens and to identify reproduction period by studying the evolution of maturity stages of the ovary.

Hepato-Somatic Index (HSI) and Oviduco-Somatic Index (OSI) and condition factor (Kn).

Monthly averages of OSI and HSI calculated from 249 females are plotted in figure 5. Three peaks were observed corresponding to the maximum annual spawning period of the population. The highest values of OSI were found in December, February, June and August and the lowest values in October, January, April, May and July.

The highest values of the HSI occurred in December, February, March, the lowest fall in October, January and April (Fig. 5). Figure 6 shows the condition factor Kn by seasons in both sexes. The values of Kn resulted overweight, thus revealing breeding events and confirming a rapid maturation occurring from September to November and from February to April when the values of Kn are very low with irregular variations.

3) Length at maturity

For the statistical method, the L50 point estimated the body size at sexual maturity at 36 cm (Fig. 7). All data are combined in Table 4. Our results confirmed values reported for Mediterranean

Author	Area	Males (cm)	Females (cm)
Ford (1921)	English Channel	50-60	57-60
Fauré-Frémiet (1942)	Atlantic	52-60	52-60
Leloup & Olivereau (1951)	Atlantic	52-60	52-60
Leloup & Olivereau (1951)	Mediterranean Sea	37-44	37-44
Zupanovic, 1961	Adriatic Sea	34	34
Collenot, 1966	English Channel	60-68	60-68
Capapé and al., 1991	Mediterranean	44	41-47
Present work *	Algeria (west)	---	36

Table 4. Summary of first sexual maturity length (L50) of *S.cyliorhinus canicula* females and males from different areas (* only females were studied to determine the size at maturity).

fisheries which differ from those from the North Atlantic where specimens length at maturity is longer than that found in the Mediterranean Sea. Total individuals' length of the monthly samples ranged from a minimum of 20 centimeters to a maximum of 50 cm. Minimum sizes correspond to females and maximum sizes correspond to males (Table 5).

B- Growth study

The values of growth parameters were calculated using the software LFDA (subroutine ELEFAN) (Kirkwood et al., 2001). Tables 6 and 7 report values of L∞ (asymptotic length), K (coefficient of growth), to (the theoretical age at which the size is zero), also for Φ (growth index). These values, once estimated for *S. canicula* specimens, were then replaced in the equation of Von Bertalanffy. Parameters obtained from the equation of Von Bertalanffy did not differ significantly between the two sexes; but asymptotic length, growth rate and growth index resulted slightly different in males.

Biometric relations observed by analysis of relative growth are shown in Table 8. This relationship indicates an upper bound of allometry (b greater than 3) for females in all months of the year.

We can say that the weight of the species grows faster than the cube of length. Such an allometric relationship was observed also in males. In fact, the upper bound also appeared in the allometry of males, except for males sampled in December and February when the values of allometry were reduced. The fitting of a and b ($W_{th}= aL^b$) was employed as input data in stock assessment models.

DISCUSSION

In our study (covering 12 months) a sample of 461 individuals of *Scyliorhinus canicula* was observed, resulting that females were more important than males. More information were obtained through the study of sex ratio based on different parameters and specimens size during the year.

We noted a fluctuation in the rate of femininity with a significant dominance during autumn and winter, which seems to correspond to a strong and early maturation period of the ovaries.

We also observed a clear statistically significant decrease in the rate of femininity tending to reach a numerical equality with males at the beginning of

Sex	Females	Males
specimens caught	249	212
Maximum size (cm)	47.4	50
Minimum size (cm)	20.1	22.2

Table 5. Size of *Scyliorhinus canicula* females and males analysed in the present study.

Sex	Females				Males			
Parameters	K	L∞	to	Φ	K	L∞	to	Φ
Result	0.57	47.70	-0.76	3.39	0.57	47.70	-0.76	3.39

Table 6: Growth parameters for *Scyliorhinus canicula* females and males.

Sex	Von Bertalanffy Equation
Females	$Lt= 47.7 [1-e^{-0.57(t+0.76)}]$
Males	$Lt = 49.23 [1-e^{-0.51(t+0.39)}]$

Table 7. Von Bertalanffy Equation.

Sex	$W_{th}= a L^b$
Females	$W_{th}= 0.00578 L^{3.176}$
Males	$W_{th}= 0.01675 L^{3.0215}$

Table 8. Biometric relation in *Scyliorhinus canicula*.

spring, i.e. in March and April, which could correspond to sexual rest or post-spawning periods; regarding the correlation between sex and body size, one can observe that size classes between 20 and 43 cm of total length are almost significantly dominated by females.

Large individuals are represented by males with a total length of 44-50 cm. This difference in size in favor of males was also reported by other authors in the Mediterranean, including Capapé et al. (1991) in the Gulf of Lions, De La Gándara et al.
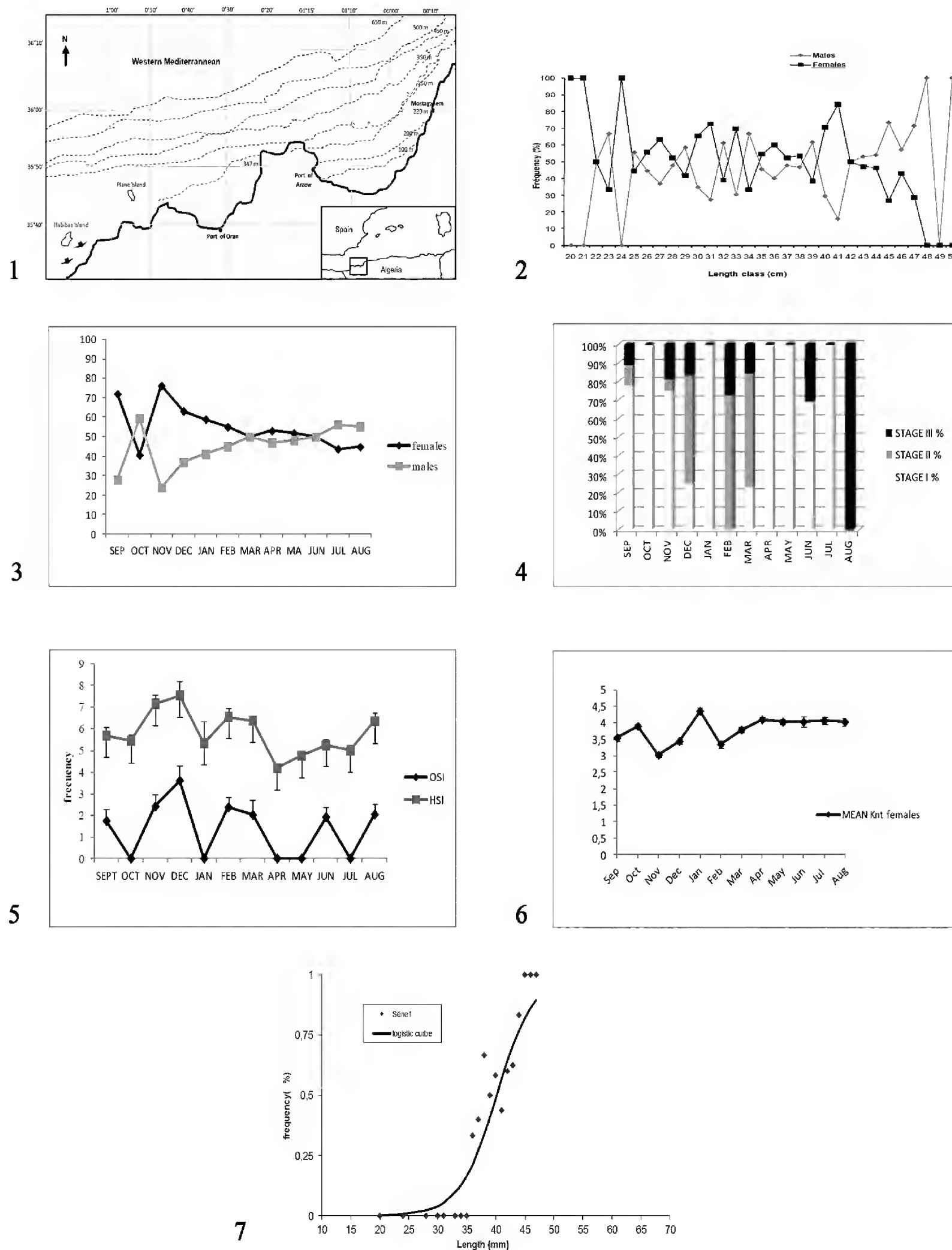
Figure 1: Study area.

Figure 2: Abundance curve. Results of χ^2 test show a predominance of one sex over the other by length of specimens (* p<0.05).

Figure 3: Distribution of males and females of *Scyliorhinus canicula* by season. χ^2 test results show a prevalence of one sex over the other per sampling month.

Figure 4: Percentages of different stages of sexual maturity in *Scyliorhinus canicula* females per month.

Figure 5: Monthly trend of OSI and HSI with standard errors in *Scyliorhinus canicula*.

Figure 6: Condition index (Kn) with standard error according to the season in *Scyliorhinus canicula* females.

Figure 7: Size of first maturity in *Scyliorhinus canicula*.

(1994) and Rodriguez-Cabello et al. (1998) along the Spanish coast; they all pointed out the size difference between females and males, which could be explained by the fact that large females are likely to be less accessible to fishing gear as they move to specific reproduction areas (Rodriguez-Cabello et al., 1998).

From the three indexes studied (OSI, HSI and Kn) we determined the spawning period of the species. Moreover, by a macroscopic approach we studied the sexual cycle of the species, the breeding of which appears to be annual (see also Capapé et al., 2008) with maximum phases of maturation occurring in December, February and March (during the laying period) and interruptions in October, January and April, corresponding to a state of sexual rest or repletion.

Similar observations were reported by Capapé (1977) however, we found periods of high ovarian maturation that differ from those reported in that paper, probably due to changes in environmental conditions as fluctuations in ocean water masses (Harris, 1952; D'Onghia et al., 1995; Mouffok et al., 2008). Ford (1921) reported that, in southern England, there were a peak in August and a minimum in September and October. While in the paper of Fauré-Fremiet (1942) these peaks were in June and January. Lo Bianco (1909), Leloup & Oliverau, (1951) and Capapé et al., (1991, 2008), maintained that this period can last all year round, without interruptions. In line with further studies on endocrine control of reproductive cycle by Sumpter & Dodd (1979), we support the idea that, although the spawning period of *S. canicula* could be quite long, it should have a maximum peak of spawning in spring and winter.

To accurately determine the period of breeding and spawning of benthic or demersal species, several indicators are generally used. Referring to ISRA-IRD (1979), it is recommended to use at least two indices when studying the reproduction of a target species. Please note that, in the present study, OSI and HSI vary in parallel and the evolution of these values is opposite to that of Kn.

We estimated the size at first maturity (L50) at 36 cm. According to Rodriguez-Cabello et al., (1998) the size at first maturity of females in the Mediterranean is smaller than that found in North Atlantic; this difference (also found in males) was explained by suggesting a possible relationship bet-

ween maturity of the species and latitude (Lam, 1983). Our results confirm and support findings obtained by different authors mentioned above suggesting that reproductive parameters of *Scyliorhinus canicula* differ from one region to another, probably under the influence of various environmental and geographic parameters (Leloup & Oliverau, 1951; Relini & Orsi-Relini, 1987; Capapé et al., 1991; Demestre & Martin, 1993; Guijarro et al., 2007) such as the passage of the Atlantic currents entering the Mediterranean through the Strait of Gibraltar rich in organic matter providing an ideal enrichment of Algerian deep waters (Cartes et al., 2002).

Finally, our results for growth curves (in line with those reported by Rodriguez-Cabello et al., 1997), strongly suggest a slow growth rate and an important longevity, up to 10-20 years, for *S. canicula* specimens.

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Ecological features of Tundra Cranes in North-Eastern Siberia (Aves, Gruidae)

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ABSTRACT   In sub-arctic tundra of North-Eastern Siberia (Yakutia region) the breeding areas of Siberian Crane, *Grus leucogeranus* (Pallas, 1773) and Lesser Sandhill Crane, *Grus canadensis canadensis* (Linnaeus, 1758), overlap. In the present paper ecological interrelations between these two crane species are reported. Siberian Crane is the dominant species and occupies more productive ecological niche such as damp lowlands. Sandhill Cranes have to content themselves with less productive but more extensive habitats such as drier and higher levels of tundra. Generally speaking, Sandhill Cranes prefer to feed in damp lowlands, as can be observed in areas where Siberian Cranes are absent. Such a displacement toward another ecological niche has not a significant impact on Sandhill Crane thanks to the plasticity and tolerance of this species.

INTRODUCTION

In tundra of North-Eastern Siberia (Yakutia region) Siberian Crane, *Grus leucogeranus* (Pallas, 1773) and Lesser Sandhill Crane, *Grus canadensis canadensis* (Linnaeus, 1758), share the same breeding area. Siberian Cranes inhabiting areas from Yana-Kolyma watershed to Kolyma River represent the eastern population of the species.

The welfare of Siberian Crane eastern population strongly influences the conservation of the species all around the world since western population now counts just a few pairs of specimens. By the present, Siberian Crane eastern population numbers up to 4004 individuals, as it was shown by the counts on the main wintering ground of the species in Poyang Lake Natural Reserve, South-Western China (Qian, 2003). For the western population, only one Siberian Crane was registered in the wintering ground in Iran during 2010-2011 (Tavakoli, 2011).

Sandhill Crane in Yakutia is represented by one from six subspecies. In the Old World, Lesser Sandhill

Crane is present in North-Eastern Russia from Kamchatka peninsula and North-Western Chukotka to subarctic tundra of north-eastern Yakutia. During the censuses of the 1980's, the number of Sandhill Cranes on breeding ground in Yakutia was estimated at 370 individuals (Labutin & Degtyarev, 1988).

Several authors reported a significant increase in SandhillCranes number along with the expansion of its breeding range westwards beginning from the second half of the 20th century (Portenko, 1972; Kischinski, 1988; Labutin & Degtyarev, 1988; Labutin et al., 1990; Poyarkov et al., 2000; Degtyarev, 2009).

Perhaps this phenomenon is associated with hunting on the Sandhill Crane in North America (Meine & Archibald, 1996). In particular, specimens number noticeably increased near-Kolyma tundra (Table 1). During this study, in 1998, a Sandhill Crane pair with two chicks was observed for the first time on the left bank of Indigirka River, 200 m west from the species breeding area limit; this finding seems to prove that Sandhill Cranes

breed near-Indigirka tundra and indicates the success of this species in its further expansion westwards (Vladimirtseva, 2002; Germogenov et al., 2003; Vladimirtseva et al., 2009).

In Indigirka basin, where their breeding ranges overlap, the two Tundra Crane species use different ecological niches (Watanabe, 2006). Siberian Cranes occupy damp lowlands near or between big lakes extending up to 15 km in length, whereas Sandhill Cranes can be often seen on higher and drier habitats. Over the last decade, in the studied area (1314 km² near-Indigirka tundra) the population of Siberian Cranes grew by four pairs and, in 2009, the population density was estimated as 0.71 ind/10 km².

In Indigirka basin, where Sandhill Cranes show a lower population density in the peripheral zone of the breeding area and share their breeding territory with Siberian Cranes, it was very difficult to carry out chronometrical observations, especially for pairs with chicks due to their constant movement resulting in short-term watching.

Chronometrical observations were made near-Indigirka tundra during summer seasons from 1998 to 2009. The highest recorded duration of continuous observations of the Sandhill Crane brood in the Indigirka basin was of 11 hours and 3 min. These data were compared with those obtained during the period 2010-2011 from a population with a high population density inhabiting near-Kolyma tundra (see Table 1).

Siberian Cranes are rare in Kolyma river basin and mostly do not breed there. The main objectives of this study were to provide data on Sandhill Crane population density, habitat conditions, breeding pair time budget and species behavior in the study area and to compare these results with those obtained for the population of Indigirka basin.

MATERIALS AND METHODS

Counts of the Crane pair numbers and observations were made from the highest points of local hills (called "edoms") using a telescope with sixtyfold magnification, as well by hiking and boating. Observations were recorded by the methods of continuous and regular (every 15 sec) recording (with mention of all details) (Dolnik, 1980; 1995).

Sandhill Crane social structure and population size were estimated within the study-area consisting of 402 km² near-Kolyma tundra, River Bolshaya Chukochya mouth (Table 2) by a total of 256.15 hours of chronometrical observations. A pair of Siberian Cranes between lakes Bolshoye Morskoye
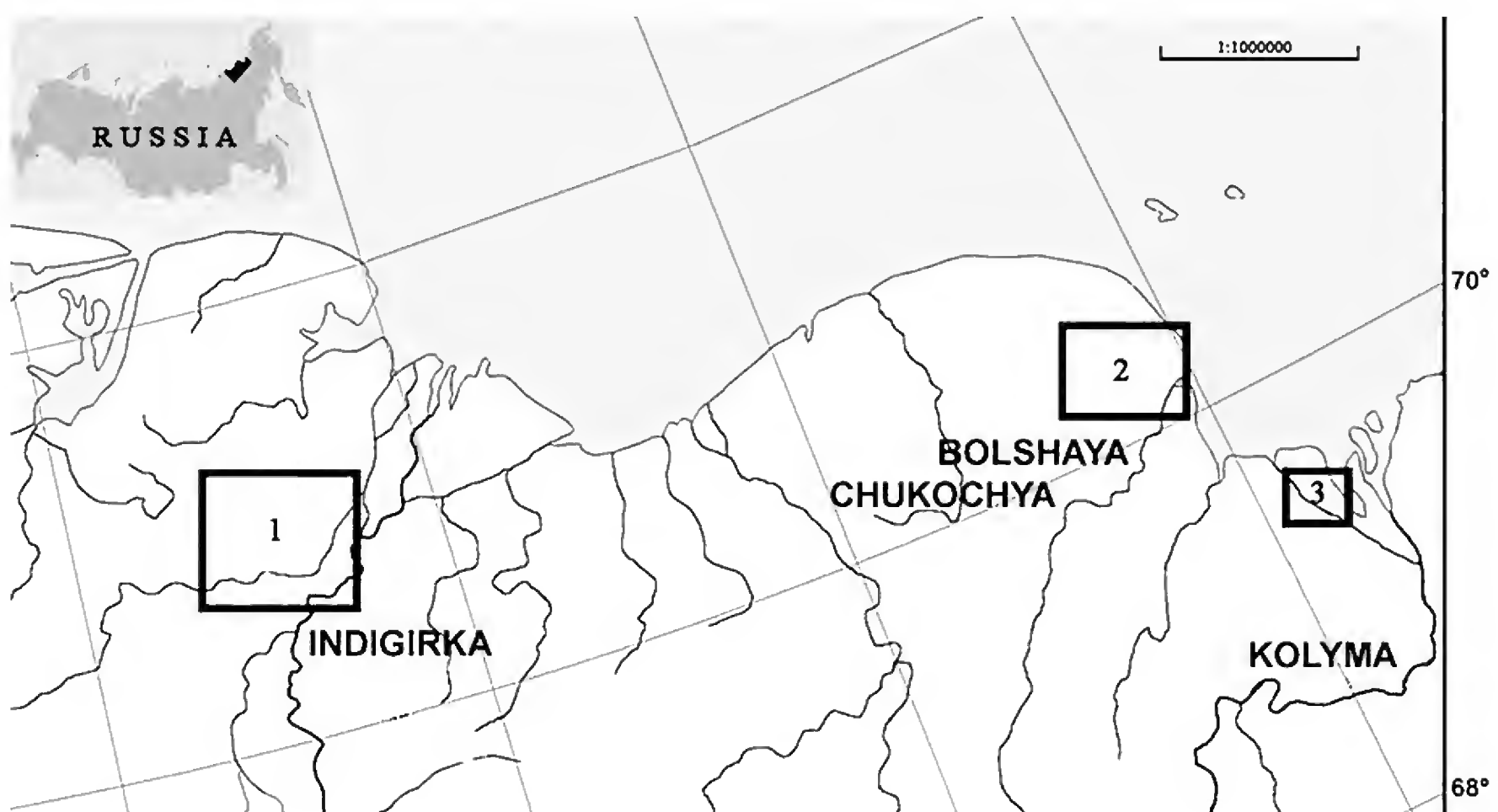

Figure 1. Research areas: 1, near-Indigirka tundra (from 1998 to 2009); 2, near-Kolyma tundra, Bolshaya Chukochya mouth (in 2010); and 3, Kolyma Delta, locality Pokhodskaya Edoma (in 2011).

Figure 2. Sandhill Crane chick, Bolshaya Chukochya River basin, and (in the small box on the right) an adult bird.

(18.2 km in length) and Maloye Morskoye (11.1 km) was registered from the watching point on the lake Vankhmat. Considerable distance from the object (15 km) did not let to see if they had any chicks. Local people registered this pair of birds for over 10 years.

RESULTS

As revealed during the chick-raising period, Sandhill cranes do not show pronounced intra-specific territorialism. Although pairs had individual breeding territories, their boundaries could easily be violated. Representatives of all social groups, pairs with chicks, pairs without chicks and single birds moved freely over a wide area and could meet and connect in groups of up to seven birds for a short time.

A comparison of time budgets between the two crane species showed that Sandhill Crane chicks are more independent than Siberian Cranes at the same age: i.e. they can feed almost without the help of their parents (Table 3). In addition, the Siberian Crane chick is given more time to rest during daylight hours.

A distinctive feature of Sandhill Cranes occurring near-Indigirka tundra was the constant move-ment associated with gathering food items, such as sedge shoots, small invertebrates, mammals (lemmings and voles) and small bird chicks, from the ground surface never showing feeding connected with digging. On the contrary, Sandhill Cranes near-Kolyma tundra spent 68% of their feeding time at the lowest elevation areas, so-called "pits", where they dig out roots of sedge using their beaks, which is typical of Siberian Cranes.

Moreover, Sandhill Cranes near-Indigirka area spent significantly more time in a state of alertness and anxiety than Sandhill Cranes inhabiting near-Kolyma tundra (where there are no Siberian cranes) and than Siberian Cranes (Table 4).

In general, time dedicated to brood care indicates that the rate of activities of Sandhill Cranes is a little more accelerated than that of Siberian Cranes. When considering the results reported in Table 4 it should be taken into account that some activities (alertness, movement and feeding) overlap in time, so that the sum of all activities during the day is over 100%.

DISCUSSION

Siberian Crane and Sandhill Crane share the same breeding area near-Indigirka tundra. Nevertheless, these species have the possibility to realize

Near-Indigirka tundra	Near-Kolyma tundra			Banks island, 1965, Yukon-Ku-skokwim Delta, 1976	Ust-Chaun lo-wland, Chukotka, 2002
Left bank of Indigirka,2009	Bolshaya Chuko-chya mouth,2010	Pokhods-kaya Edoma, 2011	Pokhods-kaya Edoma, 2007		
0.85 ind./10 km²	2.7 pairs /10 km², 5.9 ind./10 km²	4.8 ind./10 km²	4.5 ind./ km² (Degtyarev, 2009)	5.4-17.8 pairs /10 km² (Boise, 1976; Walkinshaw, 1965)	6.5-7.4 pairs /10 km² (Winter, 2002)

Table 1. Sandhill Crane population density in different years and in different parts of its range.

Adult cranes number				Breeding success		Chicks number	
Ind.	Including			Broods number	%	In 17 broods	In 21 broods
	Singles	Pairs	Groups of 3-7				
239	7	216	16	38	35.2	9	9

Table 2. Sandhill Crane population structure and reproduction in the study-area during 2010.

Activities	Sandhill Cranes		Siberian Cranes (n=5)
	Indigirka basin (n=2)	Kolyma basin (n=12)	
Absolute rest	116.09±0.02 (16.00-16.19)	16.64±0.85	14.96±0.30
Incomplete rest	8.32±0.12 (8.11-8.53)	13.71±0.08	30.46±0.51
Self feeding	1.71±0.01 (1.70-1.72)	2.05±0.92	0.71±0.82
Alarm	3.59±0.71 (3.09-4.10)	0	0

Table 3. Time (expressed in %) dedicated to daily activities by crane chicks in the study areas.

Activities	Sandhill Cranes		Siberian Cranes (n=5)
	Indigirka basin (n=2)	Kolyma basin (n=12)	
Feeding	49.86±0.59 (50.80-50.92)	50.05±0.6	32.66±0.21
Movement (no feeding)	8.41±0.4 (9.00-9.82)	2.8±0.31	2.6±0.12
Alert	6.0±0.19 (5.8-6.2)	0.9±0.55	0.1±0.60
Anxiety	14.0±0.39 (14.6-15.4)	1.0±0.09	7.5±0.21
Cleaning of feathers	0.8±0.01 (0.09-0.12)	1.2±0.41	3.8±0.32
Night's sleep	14.99±0.08 (15.90-16.08)	15.6±0.26	14.9±0.52
Feeding the chicks	32.8±0.2 (34.7-34.9)	34.9±0.14	38.4±0.19

Table 4. Time (expressed in %) dedicated to daily activities by adult cranes within the study areas.

their potential in population growth because they use two different ecological niches; Siberian Cranes occupy damp lowlands near or between big lakes, whereas Sandhill Cranes can be often seen on higher and drier habitats.

Siberian Cranes are absent in Kolyma River basin, probably because of lack of big lakes which constitute an optimal habitat for their breeding. Observations near-Kolyma River tundra showed that Sandhill Cranes with chicks spent most of their feeding time in damp and low wetlands. In the area at the mouth of Bolshaya Chukochya River, Sandhill Cranes do not compete for territories in chick-raising periods, as in Chukotka (Winter, 2002) or Alaska (Boise, 1976), thus suggesting that their food resources should be abundant enough.

Near Kolyma River tundra Sandhill Cranes feed in the Siberian Crane way: during the day, they periodically dig out parts of sedges staying in the same place. On the contrary, near-Indigirka River tundra Sandhill Cranes gather food (i.e. sedge sprouts, insects, small animals and small bird clutches or chicks) mostly from the surface, which makes them covering great distances during feeding activities.

Near Indigirka River (= the co-habitation area of the two species) Siberian Crane appears to be dominant and is replaced by Sandhill Crane in the less productive ecological niche, that is, the higher and drier areas of the tundra; while in northern-eastern tundra of Yakutia (where Siberian crane is absent) Sandhill Crane broods clearly prefer damp and low wetlands.

Sandhill Cranes are capable to use a wide range of habitats, since they are not so highly specialized and hence result more adaptable to environmental conditions than Siberian Crane. Using a less productive but more extensive habitat, Sandhill Cranes occurring in Indigirka tundra continue to expand their breeding range westwards increasing in density and number (Vladimirtseva et al., 2009).

Taking into account both growth of Sandhill Cranes number and the extension of their breeding range in Yakutia, in order to examin inter- and intra-specific relationships between Siberian Cranes and Sandhill Cranes within the co-habitation area as well as in Kolyma tundra, further studies are certainly needed. Global warming, one of the most serious threats to Siberian Crane, may lead to reduction and loss of nesting habitat for this vulnerable crane species breeding in wet lowlands close to big lakes.

At the present time, Siberian Crane and Sandhill Crane can coexist by using different ecological niches but, on the other hand, in the next decade ecological and ethological observations regarding these species will probably show the degree of danger of emerging and evolving threats menacing their existence.

CONCLUSION

1. In the tundra near Indigirka River Siberian Crane and Sandhill Crane occupy different ecological niches which strongly reduces the competitive relationship between these species and allows them to realize, at best, potential growth in their respective populations.

2. In Kolyma basin, where Siberian Cranes are absent, Sandhill Crane broods prefer to feed in wet habitats. On the contrary, in Indigirka River basin, where breeding ranges of these two crane species overlap, the dominant Siberian Crane is replaced by Sandhill Crane in the higher and dryer zones of the tundra. Such a displacement toward another ecological niche has not a significant impact on Sandhill Crane thanks to the plasticity and tolerance of this species.

3. Large-scale movement of Sandhill Crane broods in Indigirka River tundra may be due firstly to the tolerance of these organisms which, unlike Siberian Crane, are not strongly dependent on wetlands; and, secondly, to their habit of gathering food items from terrain surface which allows them to exploit more elevated terrains and explore much larger areas.

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First record of the Giant House Bat *Scotophilus nigrita* (Schreber, 1774) in Cameroon (Mammalia, Chiroptera)

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ABSTRACT   We report the first record of the Giant House Bat *Scotophilus nigrita* (Schreber, 1774) (Mammalia, Chiroptera), from Cameroon where this species was never documented before. *Scotophilus nigrita* is one of the biggest species of Microchiropterans. Some misidentifications were noted before 1978 with *S. dingani* (A. Smith, 1833) being identified as *S. nigrita*.

KEY WORDS   Chiroptera; *Scotophilus nigrita*; Cameroon; new record.

INTRODUCTION

As with many animal taxa, detailed scientific information about bats and their distribution in west-central Africa is currently often lacking. Thus, most African species are only known from a scattered portion of their geographic ranges. Hence the taxonomical and distributional status of many species in this area remains enigmatic.

This is one of the principal problems facing those who want to develop conservation or recovery plans in this area (Fenton & Rautenbach, 1998). The new record of a species in an area can be explained by two hypotheses: firstly the lack of inventory in this area and secondly a low sampling effort on this area. The main problem in central Africa is the lack of bat studies.

Recent studies in this area have demonstrated that some species, which were previously considered to be absent or rare, have been regularly caught (Cosson, 1995, Sedláček et al., 2006).

This work can be useful for better understanding of this important field of zoology and promote the necessary guidelines for the protection of bats in different geographical areas of the world; we must,

indeed, discuss further research on these special mammals for a better understanding of their biological behavior.

MATERIALS AND METHODS

On 13 April 2011, during a survey in the sahelian zone of northern Cameroon, Bakwo (with Bol) captured a single reproductive adult male in Mokolo (10°43' 943"N; 13°46' 806"E; elevation: 849 m).

The specimen is deposited in the collection of the Laboratory of Zoology of the University of Maroua under the number BFEM 072.

The individual was caught in a mist net (9 x 2.8 m) set under water across a river at 21:21 hours. This zone is characterized by a Sudano-Sahelian climate with low savannah (Suchel, 1988). The climate in the area is characterized by two seasons, with major rainfall peaks generally occurring in October (Suchel, 1988).

In our specimen, the belly is whitish with no clear boundary (Fig. 1). The predominant colour of the pelage of the back is deep chestnut (Fig. 2).
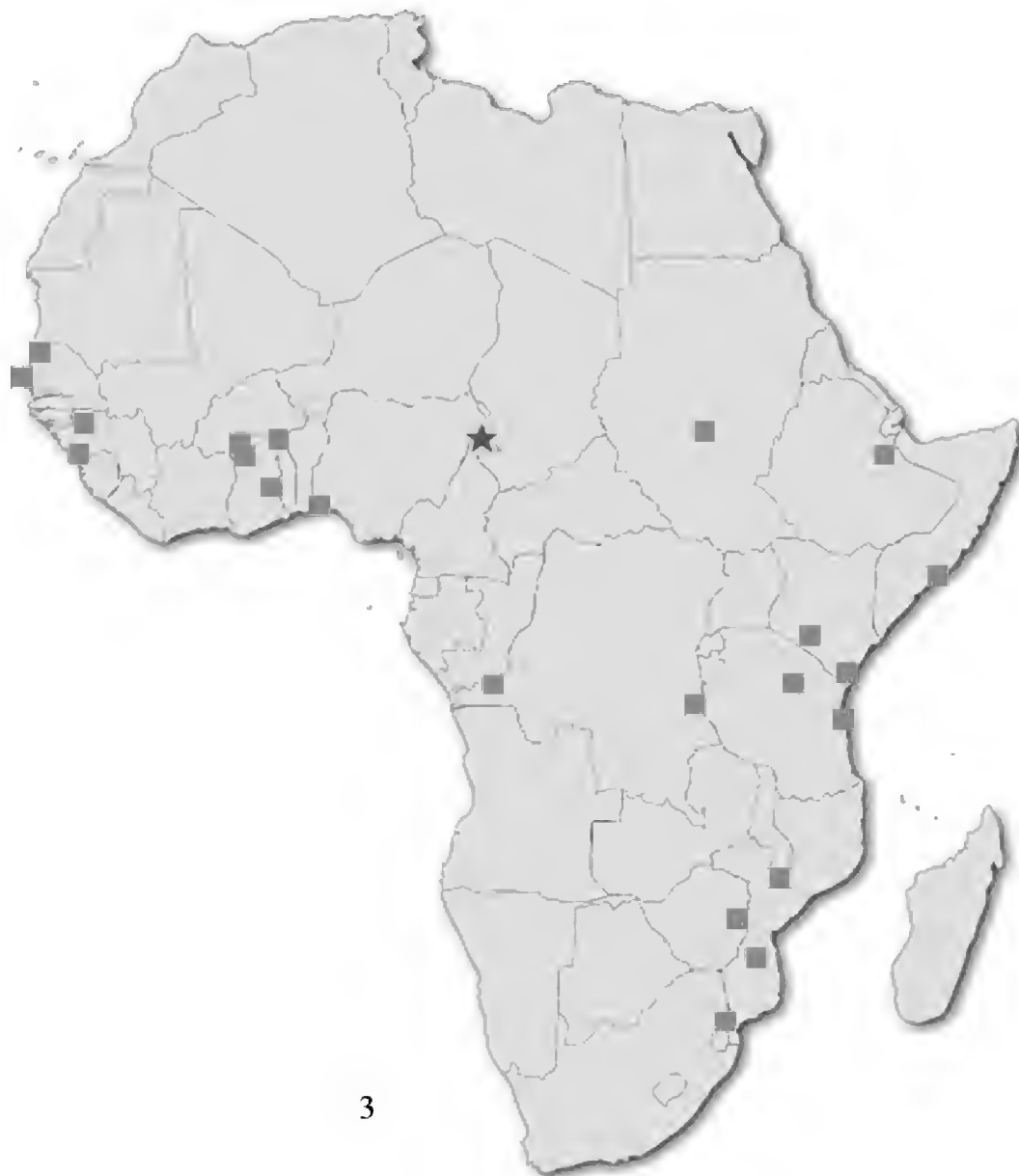
Figures 1, 2. *Scotophilus nigrita*, male collected at Mokolo, on 13 April 2011 and currently in the collection of the Laboratory of Zoology of the University of Maroua.

Figure 3. Records of *Scotophilus nigrita* (red) based on published data (African Chiropteran Report, 2011) including the recent record from Cameroon (indicated by star).

The external measurements of the specimen were measured with a dial calliper (Mitutoyo) and are as follows: FA: 84.8 mm; tibia: 34.2; ear: 19.3 mm; tail: 75.7 mm.

DISCUSSION

Based on our external measurements, we assign this specimen to the taxon *Scotophilus nigrita* (Schreber, 1774), which was not previously known from Cameroon (African Chiroptera Report, 2011). The measurements of the specimen do not exceed the variation range reported for this species given by Robbins (1978): FA: 86; and Robbins et al. (1985): FA 82.3 (77.5-88.0), tail: 78 (76-80).

The Giant House Bat, *Scotophilus nigrita* (Schreber, 1774), ranks as Near Threatened (NT) in the IUCN redlist (Monadjem et al. 2010); *Scotophilus nigrita* has been recorded as scattered records from west, east, and south-east Africa (African Chiroptera Report, 2011).

It has been reported from Senegal, Côte d'Ivoire, Ghana, Togo and Nigeria in west Africa, from central Sudan, and from western Democratic Republic of the Congo, western Kenya and Tanzania, south to Mozambique, Malawi, eastern Zimbabwe and north-eastern South Africa (Fig. 3). This species ranks among the rarest bats in Africa (Rosevear, 1965) and most information on this species is based on casual records (Happold, 1987). Most of the few records of this species in Africa have been from dry savannah sites (Happold, 1987).

The present record also comes from a savannah region and corroborates published data. However, Happold (1987) mentioned an unusual presence of this species near Lagos (Nigeria) in rainforest zone.

CONCLUSION

Scotophilus nigrita is one of the biggest species of Microchiropterans. It was originally described by Schreber in 1774 from a specimen collected in Senegal (Robbins, 1978). Some misidentifications were noted before 1978 with *S. dingani* (A. Smith, 1833) being identified as *S. nigrita*.

The new record bridges the gap between the west African and the northeast and central African distribution areas of this species (Fig. 3) and increases the number of bat species known to occur in Cameroon.

According to its previous known range, the nearest record of this species was in Lagos (Happold, 1987) i.e. about 1250 km far from Cameroon.

Further survey is needed to specify the extend of the range of this species and to determinate its conservation status.

ACKNOWLEDGMENTS

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Cerambycidae (Coleoptera) richness in Mediterranean landscapes of Spain: diversity and community structure analysis

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ABSTRACT   The aim of the present work was to analyse the diversity of Cerambycidae (Coleoptera) in 3 Spanish protected Mediterranean natural parks affected by bioclimatic conditions: La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà. Sampling was conducted by direct and indirect collection (light and Malaise traps) between 2004 and 2009. During this period, 1,102 specimens, belonging to 61 different species, were captured. Alpha, beta and gamma diversities, as well as the structure of the communities were subsequently analysed. Our results indicate that Tinença de Benifassà has higher diversity than Font Roja and Las Lagunas de la Mata-Torrevieja. Based on analysis of structural models, these communities were observed to be unstable and are composed of only a few abundant species and a large number of rare species. All 3 parks conform to log-series and log-normal distributions. These results demonstrate that it is not possible consider the habitat influence in community structure, since each habitat displays very different botanical and faunal compositions, and climate conditions.

KEY WORDS   Cerambycidae; Diversity; Community; Mediterranean landscape.

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INTRODUCTION

Mediterranean ecosystems are very important in biodiversity terms, and are thus considered hotspot areas (Myers et al., 2000). Landscapes and habitats grow in complexity over time, as a consequence of ecological processes. For example, Mediterranean forest landscapes rich in evergreen species frequently intersect with brushwood, pasture, farming and ranching areas.

In close proximity to these areas, however, it is often possible to identify zones which have been reclaimed by highly diverse natural communities after the cessation of human intervention. Despite the huge resistance displayed by Mediterranean biotopes to human pressure, isolation and fragmentation are unavoidable (Pungetti, 2003), resulting in the emergence of isolated patches in the landscape.

Saproxylic beetles play an essential role in these ecosystems, by taking part in decomposition processes essential for the nutrient cycle, and by interacting with other groups of organisms which are also important for the well-being and economy of the ecosystem, such as mites, nematodes, bacteria and fungi (Speight, 1989; Alexander, 2008).

Beetles carry these organisms from tree to tree, aiding their dissemination throughout the habitat and are also involved in pollination (Nieto & Alexander, 2010).

Significant long-term effects to Saproxylic beetles which have been identified include loss of habitat due to logging and wood harvesting and the decline of older, old-growth trees throughout the landscape, as well as the lack of land management strategies aimed at recruiting new tree generations (Buckland & Dinnin, 1993; Nieto & Alexander, 2010).

More short-term and localised threats arise from sanitation works and the removal of old trees due to safety concerns, in places subject to intense

human use (Hill et al., 1995; Johns, 1989; Grove & Stork, 1999).

Raising awareness among conservation professionals and resource managers about the needs of saproxylic organisms, who depend on tree aging dynamics and wood decay processes, is crucial, since their role in the ecosystem has far-reaching implications for land management (Kaila et al., 1997; Reid & Kirby, 1996).

A lack of intervention or minimal intervention in formerly wooded pasture areas can deter the renewal of old trees, with very damaging results, whereas livestock grazing may actually be very beneficial for the maintenance of adequate habitats (Nieto & Alexander, 2010).

The death and decay of wood offers a broad range of potential microhabitats for the spatial segregation of different saproxylic insects, according to tree species, tissue type and position within the trees. In addition to this spatial segregation, a temporal segregation follows degradation phases during wood decay. During this process, many stages can be recognised along with their specific saproxylic fauna. Saproxylic insect richness depends on the quantity and quality of dead wood available in the forest, as well as on forest size, fragmentation and management (Mendez Iglesias, 2009).

The Cerambycidae family is one of the richest in saproxylic beetles, with approximately 35,000 catalogued species (Grimaldi & Engel, 2005). Some of these species have frequently been found to be significant for the declaration of internationally important forests (Speight, 1989).

However, despite the large number of studies on this family of beetles, very few studies have been conducted on their diversity and community structure in natural areas, to improve our understanding of this coleoptera community.

In this context, the current work aimed to analyse Cerambycidae community patterns and diversity in three natural parks in the Comunidad Valenciana (Eastern Spain): La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà.

These parks enjoy an outstanding position in terms of biodiversity, emphasising their environmental significance due to their particular bioclimatic conditions. To analyse Cerambycidae communities, weekly samples were collected, and abundance, alpha, beta and gamma diversity, as well as community structure were analysed for each park.

MATERIALS AND METHODS

Three natural parks in Comunidad Valenciana were selected for Cerambycidae beetle collection (Figs. 1-3): La Font Roja, Las Lagunas de la Mata-Torrevieja and La Tinença de Benifassà, each of which features peculiar microclimate conditions.

La Font Roja Natural Park is located to the north of Alicante province, and is known for its low level of anthropogenic disturbance. The park extends over 2,298 ha, with a maximum elevation of 1,356 m. The orientation of the hill range favours cool, moist winds from the northeast, resulting in rainfall retention.

This fact, along with the steep slopes and the predominance of limestone, fosters the existence of different landscape units. Among these, deciduous forests, brushwood, scrub rock vegetation, pine forests and agricultural areas can be differentiated. In addition, each face experiences different climate conditions: the north face is classified as upper sub-humid, with annual rainfall between 600-1,000 mm; while the south face is dry, with annual rainfall between 350-600 mm. Due to high average temperatures throughout the year (15-20°C), and the low average rainfall, the park is classified as dry and thermo-Mediterranean.

Las Lagunas de la Mata-Torrevieja Natural Park is located to the south of Alicante province, and extends over 3,700 ha, 2,100 of which are covered by water. The park is notable for its saline soils, extensive wild orchid population (*Orchis collina* Banks & Sol. ex Russell), differentiated areas of *Senecio auricula* Bourgeau ex Coss and salt marsh plants of the genus *Limonium*, reed and bulrush areas with abundant grass plants such as *Arthrocnemum* sp. and *Juncus* sp., and Mediterranean areas populated by *Quercus coccifera* L., *Pinus halepensis* Mill. and *Thymus* sp. The climate is arid with an annual rainfall below 300 mm and high temperatures.

La Tinença de Benifassà Natural Park is located to the north of Castellon province, and extends over approximately 25,814 ha. The park covers an extensive and well-preserved mountainous area, encompassing numerous and widely varied landscapes associated with medium and high-altitude Mediterranean regimes and hosting a high biodiversity of fauna and flora. It is possible to differentiate forests of *Pinus sylvestris* L., *Pinus uncinata* Mill. and *Fagus sylvatica* L., *Juniperus communis* L., and *Quercus ilex* L., alternating with crops of *Prunus* sp.,
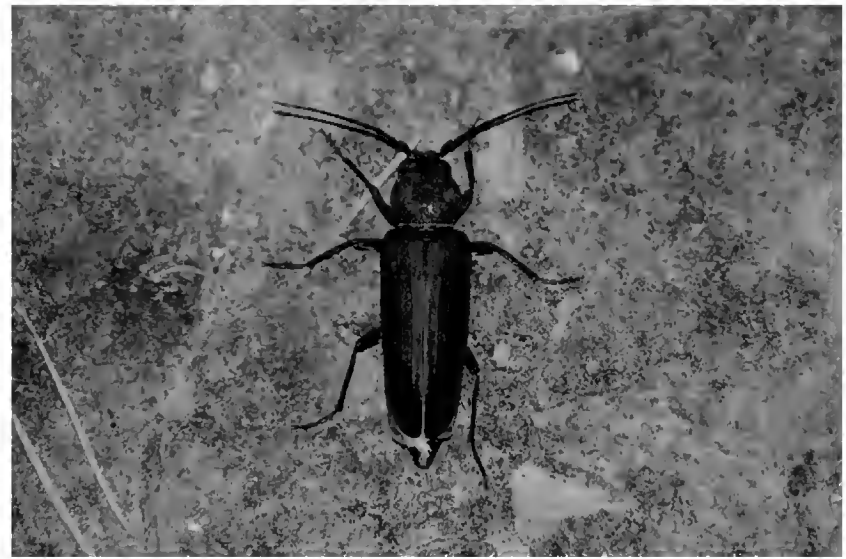
Figure 1. Natural Park of La Tinença de Benifassà.   Figure 2. Natural Park of Font Roja. Figure 3. Natural Park of Las Lagunas de la Mata-Torrevieja. Figure 4. *Arhopalus ferus.*   Figure 5. *Stenurella melanura.*

Corylus sp., etc. Climate conditions are continental humid, with annual average temperatures below 12°C: freezing conditions are possible throughout most of the year. Rainfall varies in different zones according to topographical features and the annual precipitation ranges from 600 to 1,000 l/m². The park is contained within the supramediterranean bioclimate.

Samples were collected via direct capture on plants located in the sampling areas and indirect capture with light traps and Malaise traps (Townes model), which complement each other in the capture of specimens.

Specimens were collected between 2004 and 2009 (Figs. 4-11). During this time, each natural park was visited weekly, with a few exceptions due to unforeseeable circumstances. Specimens captured via direct and light trap were kept frozen and specimens captured with Malaise traps were preserved in 70% ethanol until final preparation. Specimens were identified in the lab following criteria established by Vives (2000) and Sama (2002).

Specimens were deposited in the UVEG entomological collection. To analyse diversity and community structure, data were separately organised according to taxa presence in each park, which has been reported to be the most efficient method of interspecific comparisons (Tavares et al., 2001). Using this data, alpha, beta and gamma diversities of each park were calculated.

Alpha diversity was calculated according to taxa richness, abundance and dominance. Taxa richness was used to evaluate richness in each sampling area, and was measured using the Margalef index (Moreno, 2001). Abundance refers to faunal composition in each area (Magurran, 1991), and was measured using the Shannon index, which evaluates equity and indicates the degree of uniformity in species representation (in abundance), taking all data into consideration (Moreno, 2001; Magurran, 1991; Villarreal et al., 2004). Dominance was calculated by measuring genera and species occurrence using the Simpson index, which is often used to measure species dominance values in a given community; negative values represent equity (Magurran, 1991).

The following indexes were used to measure beta diversity: the Jaccard index, which relates the total amount of shared species with the total amount of exclusive species (Moreno, 2001; Villarreal et al., 2004); the complementarity index, which indicates the degree of similarity in species composition and abundance between two or more communities (Moreno, 2001; Villarreal et al., 2004); and cluster analysis, which is used to calculate the degree of correlation based on similarity/dissimilarity. The statistics-processing software PAST was used for calculation of these values. (Hammer et al., 2001).

Finally, gamma diversity, which indicates the degree of diversity of all involved environments, is determined from the richness index of each area (alpha diversity) and the beta diversity (Schluter & Ricklefs, 1993; Villarreal et al., 2004).

In order to complete the diversity analyses and investigate the community structure, log-series, log-normal and broken-stick models were also applied (Magurran, 1991). The log-series model represents an unstable community, composed of a few abundant species and a high number of rare species. The broken-stick model refers to maximum occupation of an environment with equitable sharing of resources between species. Finally, the log-normal reflects an intermediate situation between the previous two models (Soares et al., 2010).

Using the data obtained from the 3 parks, each of these models was applied to calculate the expected number of species – log2, grouping species according to abundance (Magurran, 1991; Tokeshi, 1993; Krebs, 1999). To test the significance of the models, expected species values were compared with those from observed species by chi-square analysis (Zar, 1999).

RESULTS

During the sampling period, a total of 1,102 specimens of Cerambycidae, representing 61 species, were collected (Table 1). Tinença Natural Park (NP) displayed the most abundance and specific richness, with 534 collected specimens and 56 species. Especially abundant were *Agapanthia cardui* (14.55%), *Stenurella melanura* (46.93%) and *Pseudovadonia livida* (10.45%).

La Font Roja NP was second in abundance and specific richness, with 390 specimens and 27 species. The most abundant were *Stenurella melanura* (46.93%) and *Chlorophorus trifasciatus* (16.53%). Finally, Las lagunas de la Mata-Torrevieja NP had 193 specimens and 13 species, of which *Agapanthia cardui*, with 62.69%, was the most abundant. In terms of alpha diversity, Tinença NP showed the most specific richness, with a value of $D_{Mg} = 8.911$,
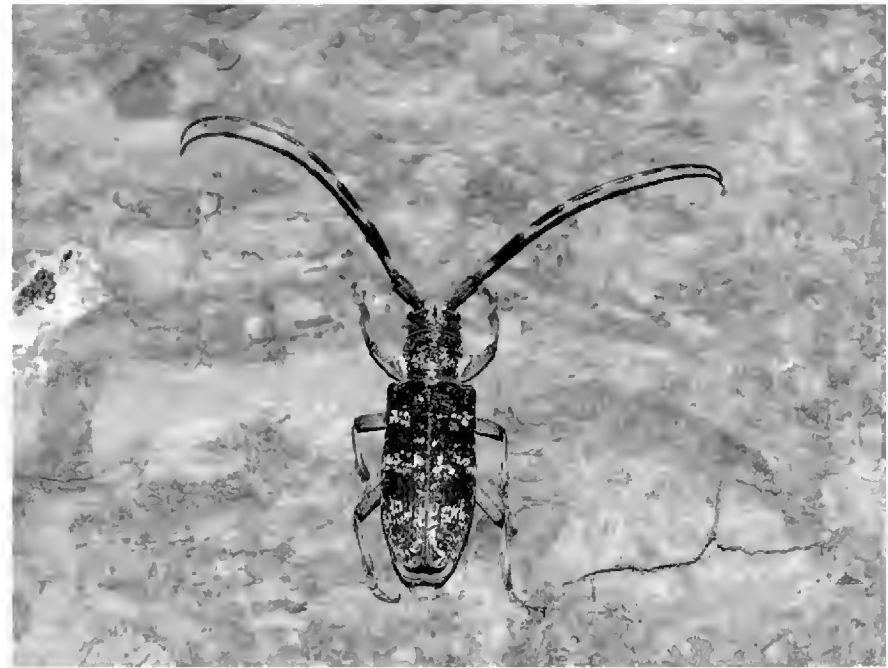
Figure 6. *Pseudovadonia livida.* Figure 7. *Stenopterus ater.* Figure 8. *Chlorophorus trifasciatus.* Figure 9. *Monochamus galloprovincialis.* Figure 10. *Agapanthia cardui.* Figure 11. *Agapanthia asphodeli.*

Francisco Javier Peris-Felipo & Ricardo Jiménez-Peydró

Species	Tinença	%	Font Roja	%	Lagunas	%
Acanthocinus aedilis (Linnaeus 1758)	2	0.37	0	0	0	0
Agapanthia annularis (Olivier 1795)	0	0	0	0	6	3.11
Agapanthia asphodeli (Latreille 1804)	18	3.36	13	3.46	26	2.59
Agapanthia cardui (Linnaeus 1767)	78	14.55	21	5.60	121	62.69
Agapanthia dahli (Richter 1820)	5	0.93	0	0	0	0
Agapanthia villosoviridescens (De Geer 1775)	4	0.75	0	0	0	0
Albana m-griseum Mulsant 1846	0	0	4	1.06	0	0
Anastrangalia sanguinolenta (Linnaeus 1761)	4	0.75	0	0	0	0
Arhopalus ferus (Mulsant 1839)	2	0.37	8	2.13	2	1.04
Arhopalus rusticus (Linnaeus 1758)	3	0.56	6	1.6	0	0
Arhopalus syriacus (Reitter 1895)	2	0.37	0	0	0	0
Aromia moschata (Steven 1809)	1	0.19	0	0	0	0
Calamobius filum (Rossi 1790)	26	4.85	6	1.6	6	3.63
Cerambyx cerdo (Lucas 1842)	3	0.56	3	0.8	0	0
Cerambyx scopolii (Füessly 1775)	4	0.75	0	0	0	0
Certallum ebulinum (Linnaeus 1767)	9	1.68	6	1.6	5	3.11
Chlorophorus pilosus (Forster 1771)	19	3.54	13	3.46	0	0
Chlorophorus ruficornis (Olivier 1790)	2	0.37	0	0	0	0
Chlorophorus sartor (Müller 1766)	1	0.19	2	0.53	0	0
Chlorophorus trifasciatus (Fabricius 1781)	30	5.60	62	16.53	0	0
Chlorophorus varius (Müller 1766)	2	0.37	0	0	0	0
Clytus arietis (Linnaeus 1758)	13	2.43	0	0	0	0
Clytus rhamni Germar 1817	2	0.37	0	0	0	0
Clytus tropicus (Panzer 1795)	1	0.19	0	0	0	0
Ergates faber (Linnaeus 1761)	2	0.37	1	0.26	0	0
Hesperophanes sericeus (Fabricius 1787)	1	0.19	0	0	0	0
Hylotrupes bajulus (Linnaeus 1758)	2	0.37	2	0.53	0	0
Iberodorcadion fuentei (Pic 1899)	1	0.19	0	0	1	0.52
Iberodorcadion suturale (Chevrolat 1862)	0	0	0	0	1	0.52
Monochamus galloprovincialis (Olivier 1795)	6	1.12	2	0.53	2	1.04
Opsilia caerulescens (Scopoli 1763)	23	4.29	16	4.26	13	13.47
Pachitodes cerambiciformis (Schrank 1781)	3	0.56	0	0	0	0
Paracorymbia fulva (De Geer 1775)	2	0.37	0	0	0	0
Paracorymbia otini (Peyerimhoff 1949)	0	0	1	0.26	0	0
Penichroa fasciata (Stephens 1831)	2	0.37	2	0.53	0	0
Phymatodes testaceus (Linnaeus 1758)	0	0	2	0.53	0	0
Phytoecia pustulata (Schrank 1776)	4	0.75	0	0	0	0
Phytoecia virgula (Charpentier 1825)	15	2.80	4	1.06	0	0
Plagionotus arcuatus (Linnaeus 1758)	1	0.19	0	0	0	0
Pogonocherus perroudi Mulsant 1839	1	0.19	0	0	0	0
Prionus coriarius (Linnaeus 1758)	1	0.19	0	0	0	0
Pseudovadonia livida (Fabricius 1777)	56	10.45	0	0	0	0
Purpuricenus budensis (Goeze 1783)	14	2.61	0	0	0	0
Rutpela maculata (Poda 1761)	2	0.37	0	0	0	0
Saperda carcharias (Linnaeus 1758)	2	0.37	0	0	0	0
Stenopterus ater (Linnaeus 1767)	21	3.92	12	3.2	0	0
Stenopterus mauritanicus (Lucas 1846)	6	1.12	0	0	0	0
Stenopterus rufus (Linnaeus 1767)	4	0.75	0	0	0	0
Stenurella bifasciata (Müller 1776)	3	0.56	0	0	0	0
Stenurella melanura (Linnaeus 1758)	63	11.75	176	46.93	0	0
Stenurella nigra (Linnaeus 1758)	36	6.72	0	0	0	0
Stictoleptura cordigera (Füessly 1775)	3	0.56	1	0.26	0	0
Stictoleptura fontenayi (Mulsant 1839)	2	0.37	0	0	0	0
Stictoleptura rubra (Linnaeus 1758)	3	0.56	0	0	0	0
Stictoleptura scutellata (Fabricius 1781)	1	0.19	1	0.26	0	0
Stromatium unicolor (Olivier 1795)	7	1.31	1	0.26	1	0.52
Trichoferus fasciculatus (Faldermann 1837)	3	0.56	1	0.53	7	6.74
Trichoferus griseus (Fabricius 1792)	5	0.93	0	0	0	0
Vesperus xatarti Dufour 1839	4	0.75	9	2.4	2	1.04
Xylotrechus antilope (Schonherr 1817)	2	0.37	0	0	0	0
Xylotrechus arvicola (Olivier 1795)	2	0.37	0	0	0	0
TOTAL	534		375		193	

Table 1. Cerambycidae abundance and average for each Natural Park.

followed by La Font Roja, with 4.218; while Lagunas de Torrevieja showed the least specific richness with a score of 2.28 (Table 2). In addition, according to the Shannon index, proportional abundance was also highest for Tinença (3.212) and lowest for Lagunas (1.399). Furthermore, results obtained with the Simpson index are in agreement with these rankings (0.9346 for Tinença, 0.7417 for Font Roja and 0.5799 for Lagunas) (Table 2).

In order to calculate beta diversity (similarity/dissimilarity), data from the different sampling areas

	Tinença	Font Roja	Lagunas
Species	56	26	13
Specimens	534	375	193
Shannon	3.212	2.032	1.399
Simpson	0.9346	0.7417	0.5799
Margalef	8.911	4.218	2.28

Table 2. Diversity and abundance of Cerambycidae captured.

were compared using the Jaccard index (Table 3). The results show a low level of comparability between species inhabiting each park; the highest value was found for the combination Tinença/Font Roja (0.383), followed by Font Roja/Lagunas (0.344).

The comparability between Tinença and Lagunas was even lower, with a value of only 0.186 (Table 3). This increased similarity between Tinença and Font Roja is due to the fact that the predominant botanical composition is similar in both forests.

On the other hand, the relationship between Font Roja and Lagunas is due to the fact that both natural parks have a high abundance of *Pinus halepensis*, which have an associated fauna of saproxylic insects. Finally, the low comparability value obtained between Tinença and Lagunas is due to significant differences in the botanical composition of these 2 parks.

With respect to the Complementarity Index (C), Tinença/Lagunas showed the highest value (0.813), again indicating the dissimilarity between species

captured in each park; while Tinença/Font Roja showed lower complementarity (0.45), indicating a stronger similarity in the specific composition of these parks (Table 3).

These results were subjected to cluster analysis using a Jaccard cluster (Fig. 12). Gamma diversity grouped all 3 parks, yielding a value of 62.

	Tinença	Font Roja	Lagunas	
Tinença	0	0.383	0.186	J
Font Roja	0.45	0	0.344	a c c
Lagunas	0.813	0.655	0	a r d
Complementarity				

Table 3. Comparative of Complementarity and Jaccard indexes values for Cerambycidae in each park.
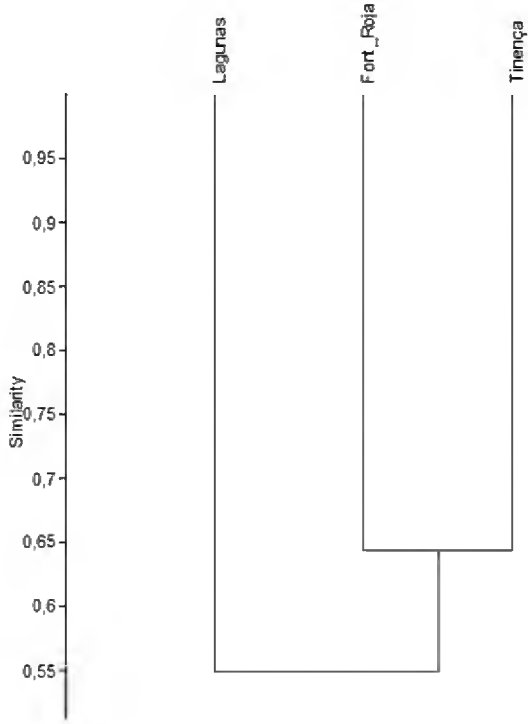

Figure 12. Cluster of Cerambycidae per NP.

Tinença, with 57 captured species, displayed the most diversity, followed by Font Roja (26) and Lagunas (13).

Finally, analysis of the community structure of Cerambycidae in each park revealed agreement with log-series and log-normal models, with p-values greater than 0.05, while no parks matched the broken-stick model (resulting p-values were below 0.05) (Table 4).

| | Log-series | | | | | | Log-normal | | | | | | Broken-stick | | | | | |
| | Font Roja | | Tinença | | Torrevieja | | Font Roja | | Tinença | | Torrevieja | | Font Roja | | Tinença | | Torrevieja | |
Class	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f	exp f	obs f
0	-	-	-	-	-	-	2.75	0	3.75	0	1,16	0	-	-	-	-	-	-
1	9.66	11	23.26	25	4.69	6	7.40	11	17.71	25	3,51	6	3,27	11	10,22	25	1,48	6
2	3.62	3	8.50	13	1.76	0	3.41	3	9.01	13	1,5	0	2,87	3	8,31	13	1,32	0
3	3.76	4	8.49	5	1.83	4	3.54	4	9.17	5	1,53	4	4,74	4	12,25	5	2,22	4
4	3.57	6	7.49	4	1.74	1	2.89	6	6.91	4	1,24	1	6,44	6	13,38	4	3,12	1
5	3.01	1	5.47	6	1.48	1	2.01	1	3.94	6	0,87	1	5,96	1	8,17	6	3,02	1
6	2.09	1	2.87	3	1.04	0	1.11	1	1.72	3	0,49	0	2,56	1	1,67	3	1,32	0
7	1.00	0	0.81	1	0.51	1	0.50	0	0.56	1	0,23	1	0,24	0	0,04	1	0,09	1
8	0.24	1	0.07	0	0.10		0.19	1			0,14	0	0,00	1			0,00	0
9	0.01	0					0.08	0					0,00	0				
	$X^2 = 7.24$		$X^2 = 5.67$		$X^2 = 6.77$		$X^2 = 9.57$		$X^2 = 10.23$		$X^2 = 7.91$		$X^2 = 1271.1$		$X^2 = 57.64$		$X^2 = 28.85$	
	$p = 0.5106$		$p = 0.4607$		$p = 0.4522$		$p = 0.2961$		$p = 0.1152$		$p = 0.3402$		$p = 0.0000$		$p = 0.0000$		$p = 0.0001$	

Table 4. Expected specific frequencies for each of the models used and statistical comparison with observed frequencies.

DISCUSSION

Alpha diversity results show that Tinença de Benifassà NP has higher diversity and specific richness than the other 2 parks. In addition, a comparison of the results for each park reveals notably disparate values, due to wide differences in the number of identified species. This is corroborated by the dissimilar values of the Shannon and Simpson indexes, indicating a lack of similarity in the distribution of dominant species.

Beta diversity results suggest that the three parks under consideration in the present study are markedly different in specific composition. Despite this low similarity, the Complementarity index shows that Tinença NP and Font Roja NP do have some similarities in their specific composition.

Taken together, these data suggest that Tinença NP has the highest biodiversity among the three parks, each of which contains a specific Cerambycidae faunal composition. This correlates with the different botanical compositions and habitats present in each park, since the cycle of each Cerambycidae species (with the exception of a few, less specialised ones) is associated with certain plant species (Linsley, 1959; Vives, 2000). In contrast, analysis of the structural models of these communities indicates that Cerambycidae communities in all of these parks fit log-series and log-normal models, which means that they include a few abundant species and a number of rare species.

Thus, community structure is not determined by habitat, because all three parks display very different faunal and botanical compositions and bioclimates. Community structure also appears to be unaffected by human action, because while Lagunas de la Mata-Torrevieja NP is fully encircled by roads and housing, Tinença NP has remained virtually free from anthropogenic pressure. To conclude, studies on biological diversity and community structure are vital for the development of a better understanding of ecosystems, and for the correct adoption of measures for the conservation and maintenance of biodiversity (Pyle et al., 1981; Pearson & Cassola, 1992; Kremen et al., 1993).

ACKNOWLEDGMENTS

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Can a simple Pelagic-Demersal ratio explain ecosystem functioning?

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ABSTRACT

In quantity terms, the proportion of the total marine fish landings which is accounted for by pelagic fish has increased continuously, with large oscillations reflecting natural variations of resources productivity and fishing strategies. The aim of the present work is to assess this trend in different Mediterranean fishing areas from 1970 to 2005 using the Pelagic/Demersal ratio (P/D). The P/D ratio is a simple ecosystem indicator based on commercial landings and provides a measure of the status of the fish community also in data-poor fisheries situations. Simple statistical techniques were used to study fishery ecosystem through the collection and comparison of geographical parameters as chlorophyll-*a* (Chl-*a*) pigmentation intensity and rainfall. In all the Mediterranean the P/D ratio appears to be correlated with the mean Chl-*a* value and increased with time, this may depend both on a better availability of nutrients in the water column and the overexploitation of resources. The areas where there is a greater presence of zones of upwelling and nutrient inputs are the ones with the highest values of the index. Additionally, comparison with the analysis of the multispecies landings shows that the trend of the index is influenced by the landings of Clupeidae and Engraulidae, a fact showing that fisheries in these areas are increasingly relying on the smaller, short-lived fishes from the lower part of marine food webs.

INTRODUCTION

There is a growing understanding that exploited fish populations must be considered as integral components of ecosystem function, rather than units operating independently of their environment (Cury & Christensen, 2005). Internationally, there has been wide recognition of the need to move towards an ecosystem approach to fisheries, a development spearheaded by FAO through their Code of Conduct for Responsible Fisheries (Garcia, 2000), and supported by many regional and national institutions.

A special attention has been focused on fishing in the Mediterranean Sea, where significant ecosystem changes have become evident in recent decades (Zaitsev, 1994; Caddy et al., 1995; Pauly & Watson, 2004).

FAO data show that landings from marine fish species (about 400,000 tonnes) has increased continuously, with large oscillations reflecting natural variations of resources productivity as well as probably boom and bust fishing strategies.

The modernisation of small- and large-scale fishing fleets (i.e., larger boats, higher tonnage and engine horsepower, improved fishing gears, use of high-technology equipment) led to the expansion of fishing in areas previously inaccessible (Stergiou et al., 1997).

As a result, new 'resources' started to be exploited, mostly at high trophic levels. Moreover, while

earlier studies suggest that the Mediterranean was originally very nutrient-limited (Murdoch & Onuf, 1972), recent researches show that the ecosystem is significantly affected by nutrient run-off over the last years.

Pelagic fishes are generally influenced by nutrient enrichment when it stimulates the plankton production (Caddy, 1993), while demersal fishes are influenced by the dynamics of benthic community, which generally responds negatively to the conditions of excessive enrichment (De Leiva Moreno et al., 2000).

The aim of the present work is to assess this trend in the Mediterranean Sea with the use of the ecosystem indicators. These indicators are to be estimated by fishery, environmental data and simple statistical techniques.

The Pelagic/Demersal index is a simple indicator that can be derived from commercial statistics. This ratio synthesizes the structure and functioning of the ecosystem in time and space and, in turn, how fisheries and eutrophication influence them (Libralato et al., 2004).

In fact, an increase in the P/D ratio of landings would seem to imply either an increase in forage fish abundance due to predatory release or environmental change. The decline of top predators stocks due overfishing leads to expansion in biomass of pelagic fishes. A similar result may occur with eutrophication, because the demersal resources are adversely affected by hypoxia resulting from excess primary production, which has less negative effects (or may even be positive) for pelagic species.

For this reason, the trend of the P/D index was compared with multispecies landings, with an independent index of primary production, namely the surface concentration of Chlorophyll-*a* (Chl-*a*), and with an index of potential land run-off impacts on marine fisheries such as precipitation to the sea surface.

The present study shows the potential of the Large Marine Ecosystem approach to examine these phenomena in the whole Mediterranean fishery ecosystem, in order to obtain an integrated insight of environmental and fishery issues.

The innovativeness of this approach is the consideration of the ecosystem as a whole including all the geographical, biological and ecological interactions, allowing the acquisition of new knowledge of coastal and marine ecosystems (Pennino et al., 2011).

MATERIALS AND METHODS

Fishery data was achieved from the GFCM (General Fisheries Commission for the Mediterranean) database (www.fishbase.org) that presents annual statistics allocated by countries, species items and statistical divisions, of capture production in the Mediterranean and Black Sea region for the period 1970-2005. For statistical purposes the Mediterranean GFCM region, which coincides with the FAO fishing "Area 37- Mediterranean and Black Sea", has been split into seven divisions (Fig. 1).

We have only analyzed the data of Mediterranean Sea, excluding those of the Black Sea. Landings data refer to nominal catches of 251 different species, not biomasses, and refer legal and reported large- and small-scale fisheries, excluding recreational or sport fishing.

These are collected by the national institution and reported to FAO by Member Countries. The data exclude production from marine aquaculture practices and statistics for marine mammals and seaweeds. The P/D index is estimated as the ratio between pelagic species and demersal species, that were defined by trophic information that classify the diet of adults of each commercial species, and were extracted from Stergiou & Vasiliki (2002) and fishbase website (http://www.fishbase.org). The P/D ratio was calculated for all 35 years of time series and for each division.

Subsequently, the index trend was compared with their multispecies landings grouped in 15 groups according to trophic level. The trophic level of each group is a mean of the different values that exist for a given species, obtained from Fishbase (www.fishbase.org) and from Stergiou & Vasiliki (2002). The environmental data used in this study were acquired using the "GES-DISC Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni), as part of the NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC)" (http://ocean-color.gsfc.nasa.gov/).

An independent index of primary production, namely the surface concentration of Chlorophyll-*a* (Chl-*a*) was used based on remote sensing imagery from 1998 to 2005. Obviously primary production depends on a range of factors, including light, light penetration, temperature, which could not be taken into account here for the absence of comparable

quantitative data with a broad temporal and geographical coverage.

Nevertheless, the mean annual value of Chl-*a* is an index of primary production that represents the seasonal production of the marine area considered. To extract and analyze the Chl-*a* data we used the function "Lat-Lon Map, Time-averaged" that provides a time-averaged colour data plot for a specified area. The values plotted are the mean value of the data product calculated for year. After adjusting for different grid referencing systems, maps of the GFCM subdivisions were superimposed on images of mean Chl-*a* values, in order to obtain specific information for each fisheries subdivision.

We analyzed the data of rainfall to the sea surface to assess a nutrient input for every division and year of the series. The annual mean data are extracted with the same function "Lat-Lon Map, Time-averaged", as mm/hr for rain rate for mm for accumulated rainfall. The source is TRMM and Other Satellite Monthly 0.25° x 0.25° Rainfall Data Product (3B43 Version 6).

RESULTS

Balearic

The area of Mediterranean Sea that has the highest values of P/D ratio is Balearic with a mean of 3.15 (Table 1). The trend of the index reaches the highest values in 1988 with 4.32 and in 1994 with 3.97 (Fig. 1). Comparing this P/D trend with the landings it can be seen that in those same years there have been increases in the landings of the class Clupeidae with respectively 146,704 and

Divisions	Chl-*a* (mg/mm^3)	Rainfall (mm/Km^2)	P/D index
Balearic	0.45	583	3.15
Gulf of Lions	0.79	618	2.80
Sardinia	0.31	624	0.45
Adriatic	0.95	911	0.90
Ionian	0.39	454	0.80
Aegean	0.27	559	1.23
Levant	0.68	356	0.80

Table 1. Mean of Chlorophyll-*a*, Rainfall and Pelagic/Demersal index for all Mediterranean divisions (1998-2005).

172,747 tonnes (Fig. 2). In the first half of the 80s landings of this class suffered a decline, while increasing those of the class Engraulidae (Fig. 2).

The analysis of the time series shows a negative relationship between these classes, i.e. any decrease in landings of Clupeidae is offset by an increase of landings of Engraulidae. These two categories are respectively 55% and 10% of total landings of Balearic. The most representative species in the class Clupeidae is the European sardine (*Sardina pilchardus*), while in the class Engraulidae is the European anchovy (*Engraulis encrasicolus*).

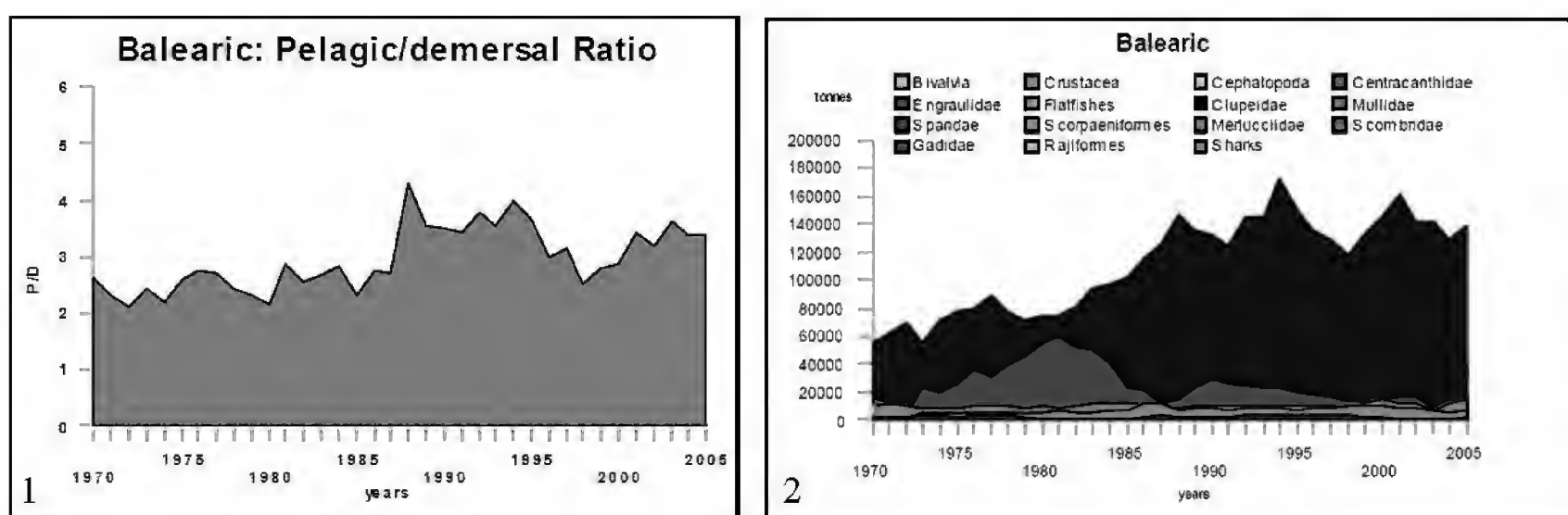The index of primary production, calculated by the time series of 1998-2005, shows constant trend

Figure 1. Pelagic/Demersal ratio of Balearic. Figure 2. Group's landings of Balearic.

with a minimum value of 0.41 (mg/mm^3) in the first year of the series, and a maximum of 0.48 (mg/mm^3) in 2001. The peak of Chl-*a* in 2001 is also found in the values of P/D index and corresponds to an increase in Clupeidae landings (Fig. 15).

The increased intake of nutrients in these years is not found in the trend of Chl-*a*, but the trend is reflected in the P/D ratio. In fact in 2003 the index recorded a value of 3.63, the highest in the last years series. At the species level in the same year class Scombridae landings increased of 11,000 tonnes.

The precipitation levels remain fairly constant across the years with values around 500 mm, except in 2002 and 2003, which recorded an average of 700 mm (Fig. 16). Another factor to take into account is that Balearic receives inflows of Atlantic water with significant inputs of nutrients with important upwelling occurring in the Alboran Sea and along the Algerian coast (Estrada, 1996; Caddy & Oliver, 1996).

Gulf of Lions

After the Balearic, the Gulf of Lions is the area with the highest average P/D, with a value of 2.80 (Table 1). The higher values of the time series are recorded in the early years, matching the biggest landings of the class Clupeidae and Engraulidae. The two classes are the 45% and 16% of the total landings. The minimum values are found in 1986 and 1982 (1.2 and 1.13) corresponding to an increase in the landings of the Bivalvia (Figs. 3 and 4). In 2003 there was a further decline in the P/D index, given the increased Merluccidae landings (Fig. 4).

In the same year the index of primary production shows its lowest value (0.69 mg/mm^3). The year 2001 shows the highest peak in the trend of Chl-*a*, as in Balearic, and corresponds to an increase in the P/D index and in the Engraulidae landings (Fig. 15).

The index P/D shows a declining trend in 2005 correlated with a decrease in landings of small pelagic species, but not with the concentration of Chl-*a*. The average rainfall is one of the highest in the Mediterranean, taking into consideration that it is the smallest division, and also the area receives considerable inputs from the river Rhône.

In 2001, when the trend of Chl-*a* and the P/D ratio record the maximum value, the level of rainfall in the area is minimal (Fig. 16). The maximum value of precipitation is recorded in 2002 (834 mm), year when the landings of the class Engraulidae increase of 4,000 tonnes, while those of class Clupeidae decrease by 3,000 tonnes.

Sardinia

The lowest P/D index occurs in the Sardinia division and remains below unity for the entire time series, with a mean the 0.45 (Table 1). Only in its first decade in which landings of Engraulidae and Clupeidae are high, the values exceed the unit (Figs. 5 and 6). In recent decades they have been represented mainly by the class Bivalvia. Until 1986 the landings of small pelagic fish are between 20,000 and 30,000 tonnes.

In these years a negative relationship is apparent between the landings of Engraulidae and Clupeidae, i.e. a rise in landings of one group reflects a decrease in the other group. Since 1987 the landings show a sharp drop of 20,000 tonnes. Only in 1993 the Engraulidae class has a peak of 10,000 tonnes, while Clupeidae in 1999, 2003 and 2005.

The P/D index shows an increase only in 1999 and 2005. This is because the index is heavily influenced by the landings of Bivalvia starting in the mid 80s; when landings of this fall in 2005, the index increases up to a value of 0.82. Values of P/D index less than 1 indicate a prevalence of demersal fishes compared to pelagic species.

The landings of this area, unlike others that have a high prevalence in the total landings of pelagic species, have a uniform distribution in all classes (Fig. 6).

Furthermore, in this area most of the fishing boats are mainly of small-scale fishing, which corresponds to a different environmental impact. The index of primary production shows a constant trend with a maximum 0.36 (mg/mm^3) in 2005, coinciding with the increase of the Clupeidae landings and the P/D ratio (Figs.15 and 5).

The minimum value is recorded in 2001 (0.27 mg/mm^3). It is surprising that maximum and minimum values are close in time, configuring a quite erratic trend in last years. The decrease of Chl-*a* in 2001 also finds its counterpart in the trend of rainfall. Indeed, the trend remains constant throughout the series with an average of 624 mm and records the minimum value in 2001 with 520 mm (Fig. 16).

Adriatic

De Leiva Moreno et al. (2000) found a mean value of P/D equal to 3.76 in the Adriatic for the historical series 1978-88. From our analysis, the mean P/D is 0.90; years from 1978-88 show the highest values of the index, but always less than 3 (Fig. 7).
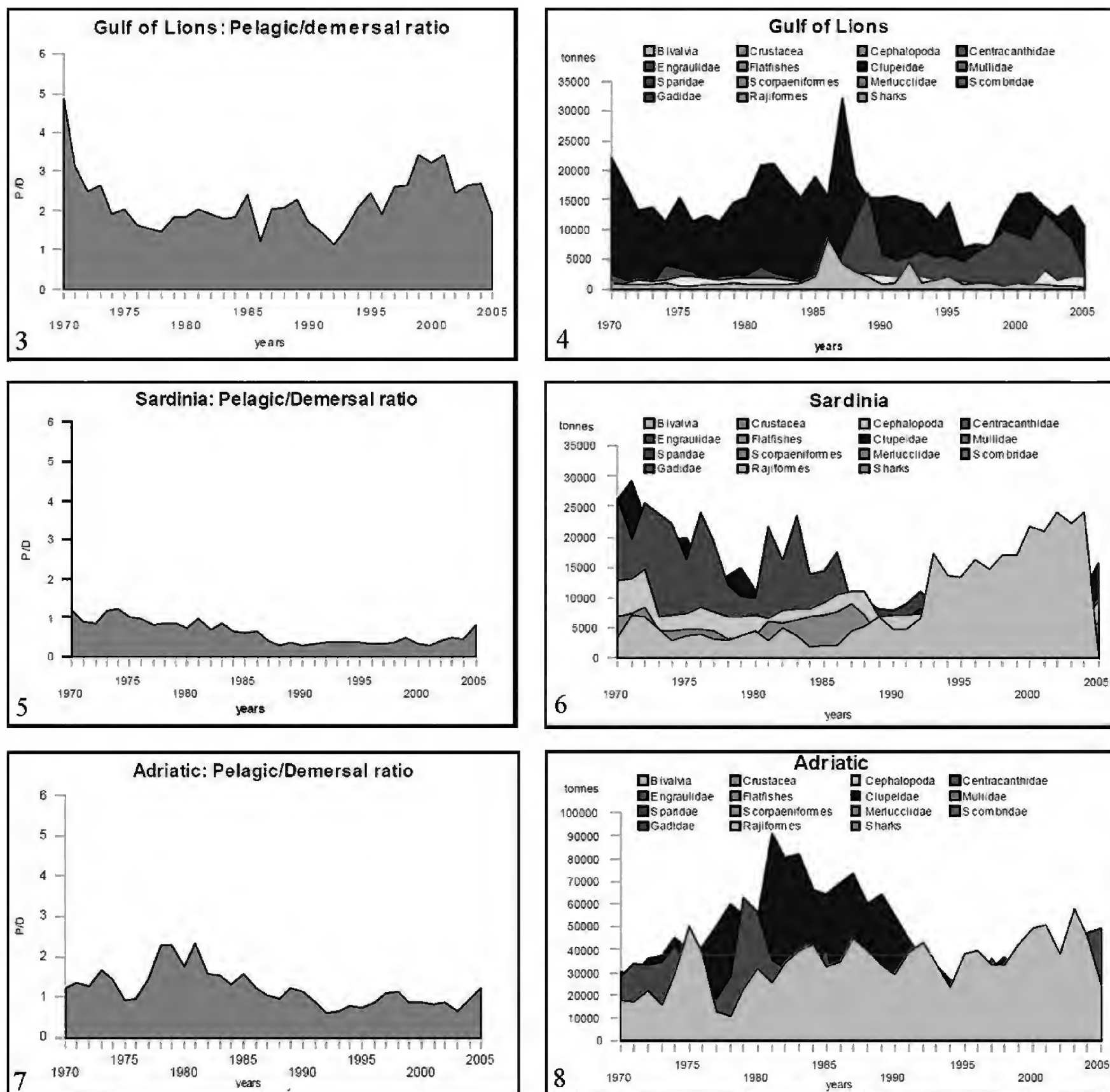
Figure 3. Pelagic/Demersal ratio of Gulf of Lions. Figure 4. Group's landings of Gulf of Lions.
Figure 5. Pelagic/Demersal ratio of Sardinia. Figure 6. Group's landings of Sardinia.
Figure 7. Pelagic/Demersal ratio of Adriatic. Figure 8. Group's landings of Adriatic.

It is known that the Adriatic is under the influence of the rather polluted river Po which brings in around 330,000 t of nitrogen and 28,000 t of phosphorus annually (Degobbis, 1989), and seasonally intense hypoxia of the upper Adriatic is caused by phytoplankton blooms (Legović & Justić, 1997).

Moreover, the analysis of the level of rainfall throughout the Mediterranean shows that the Adriatic has the highest average (911 mm), confirming the major nutrient input from this area. According with these reasons we would expect high values in the index; the analysis by species notes that large quantities of landings of Bivalvia affect strongly the index (Fig. 8). This class represents 23% of the landings of the area and it is an important local fishery resources, especially in the lagoon of Venice, where the species of the genus *Tapes* are heavily exploited (Granzotto et al., 2003).

Indeed the index P/D, calculated without the landings of the Bivalvia reaches values equal to 4. The index records the highest values in 1979 (2.31), at the peak in landings of Engraulidae (90,000 tonnes), and in 1981 (2.32), at the peak landings in the class Clupeidae (62,000 tonnes).

Over the years 1986-1995 the class Clupeidae undergoes a sharp collapse in the landings and the index P/D shows a declining trend reaching a minimum value of 0.63 in 1992. Comparing the values of Chl-*a* with the other areas, it is clear that the Adriatic is the area with the highest mean (0.95 mg/mm^3). Analyzing the time series in the primary production is noted that the minimum value was recorded in 2003 (0.64 mg/mm^3) (Fig. 15).

The index P/D shows a positive relationship with the trend by highlighting the minimum value of 0.68 in the same year, reported probably with the highest peak of the whole series of class Bivalvia. In the same year the trend of rainfall records the minimum value (720 mm) (Fig. 16).

In 2002 and 2004 the level of rainfall and Chl-*a* reached the maximum value and the P/D ratio seems to follow these maximums, presenting P/D a slightly increase (Figs. 7 and 8). Landings by species show in 2002 a decrease of 7,000 tonnes in the Engraulidae class, while in 2004 increase of 16,000 tonnes. In 2002 also landings of Bivalvia suffered a collapse and, after a recovery in 2003, continue to decline (Fig. 8).

Ionian

The Ionian has a mean P/D ratio of 0.80, with values of less than 1 for the entire series (Table 1). The 19% of total landings is the Cephalopoda class with a sharp increase in 1988 of 20,000 tonnes. In this area the values of the index and the analysis of the landings do not seem to support that there is a clear predominance of pelagic fish on groundfish (Figs. 9 and 10). In fact, 12% of the landings belongs to the class Merluccidae that significantly reduces the value of the index (Fig. 10).

The Chl-*a* index in this area is generally in the range 0.20-0.30 mg/mm^3 and remains constant for the entire time series. After Levant, Ionian shows the lowest average (454 mm) in the level of rainfall, despite being the largest division of the Mediterranean. The trend of rainfall remains constant over the years with values ranging between 500 and 400 mm, except in 2000 where it reached 300 mm (Fig. 16). In the same year also the Chl-*a* registered its lowest value (0.37 mg/mm^3) (Fig.15). In 2003, the values of Chl-*a* and rainfall reach the maximum, while the P/D ratio decreases and the trend of landings by species shows a joint decline in the landings of the class Clupeidae, Sparidae and Scombridae.

Aegean

The Aegean shows a mean P/D ratio of 1.23. The values are higher in the first four years and between 1979 and 1985, reflecting high landings of classes Clupeidae and Engraulidae (Fig. 11). The two categories account for 22% and 15% of the total landings. In correspondence of the years in which values of the index are rising, nutrient inputs increased under the influence of river run-off and Sea of Marmara inflows (Friligos, 1989). Although in recent decades the landings of Clupeidae and Engraulidae classes are significantly increased, values of P/D are less than 2, because there is also a large increase in landings of the class Bivalvia and Crustacea (Fig. 12). The Aegean is considered an oligotrophic area with biological production significantly nutrient-limited. Low levels of surface Chl-*a* pigmentation seem to confirm this feature. In fact the trend of Chl-*a* is constant with values ranging from 0.30 and 0.20 mg/mm^3 (Fig. 15).

As far as concerns level of precipitation, the values fluctuate between 500 and 700 mm, with a minimum of 405 mm in 2000 (Fig. 16). In the same year the Chl-*a* shows a minimum value of 0.26 mg/mm^3, and the P/D ratio declines. In this year landings of Engraulidae suffer a decline of 4,000 tonnes, while the class Clupeidae increase landings of 6,000 tonnes.

The level of rainfall reaches its peak in 1998 and 2002, respectively with 700 and 600 mm. During those same years, landings of Clupeidae show an increasing trend, while the Chl-*a* does not show values relatively high.

Levant

The P/D ratio for Levant is generally in the range 0-1 and has remained relatively constant, with a mean of 0.80 (Fig. 13). The highest values of the P/D index are between 1993 and 1997 (Fig. 13). Over the same period the landings of the class Clupeidae have suffered an increase of 30,000 tonnes (Fig. 14), and in fact is the category which represents the 30% of the total landings. The values of Chl-*a* in the Levant area are in the range between 0.63 and 0.74 mg/mm^3 (Fig. 15).

The maximum value is recorded in 2002. In the same year P/D index reaches the minimum value, presumably due to an increase in landings of the Bivalvia, Mullidae and Crustacea.
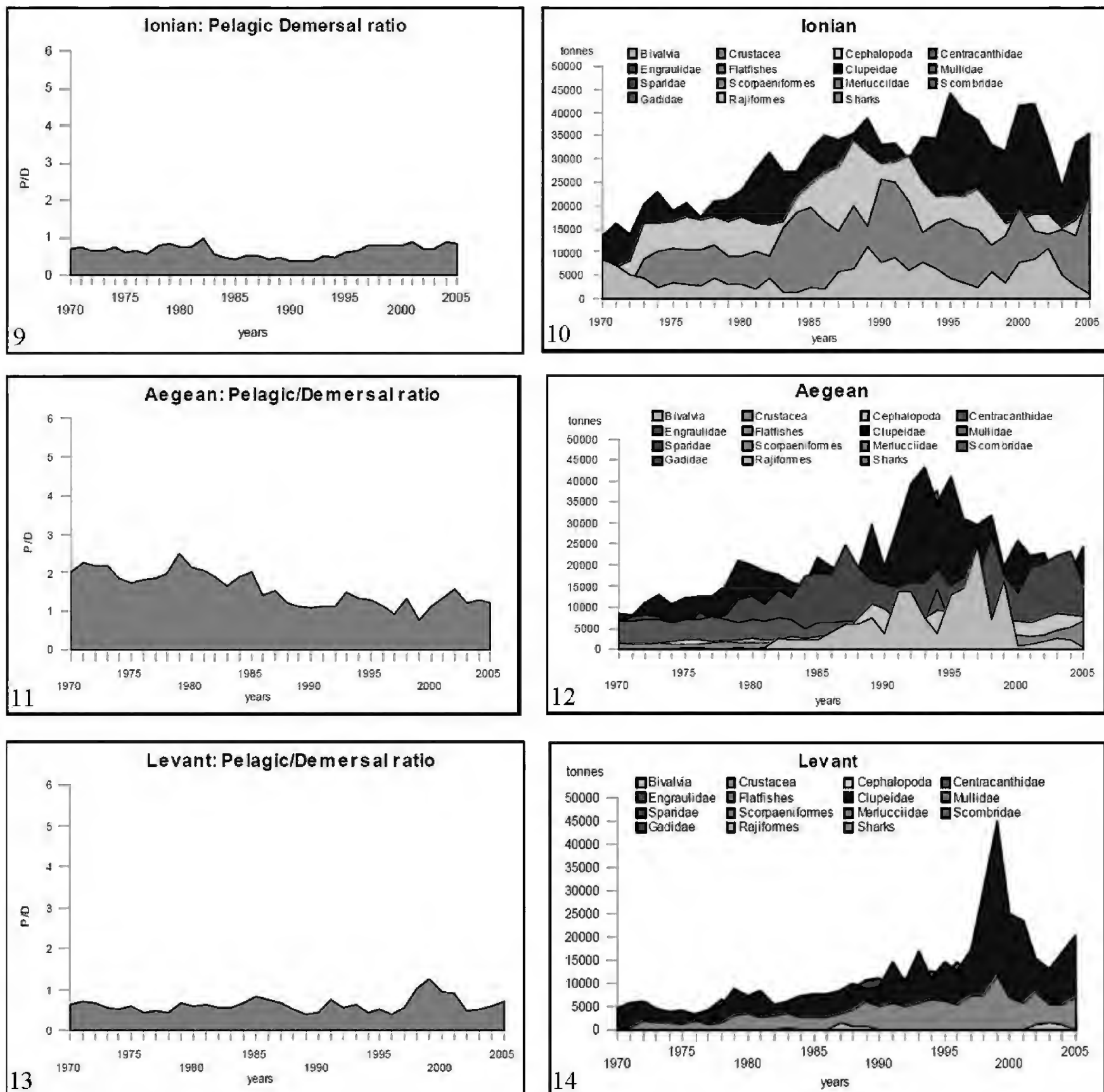
Figure 9. Pelagic/Demersal ratio of Ionian. Figure 10. Group's landings of Gulf of Ionian.
Figure 11. Pelagic/Demersal ratio of Aegean. Figure 12. Group's landings of Aegean.
Figure 13. Pelagic/Demersal ratio of Levant; Figure 14. Group's landings of Levant.

The class Clupeidae undergoes an increase in landings of 30,000 tonnes between 1993 and 1999. Later in 2001 show a decline of 20,000 tonnes, with a minimum of 16,000 tonnes in 2003.Only in 2005 the landings increased another time; the Levant is the area with the lowest average rainfall (356 mm).

In 2001 alone, the trend peak was at 400 mm. The minimum value is recorded in 1999 (251 mm) (Fig.16). In the same year landings of Clupeidae increase of 15,000 tonnes and the P/D index recorded the highest value (1.26).

DISCUSSION

This study supports the idea that analyses of the relationships between landings of pelagic and demersal marine fish are useful indicators of overall trends in fisheries; for example, since the demersal fish stocks are generally in higher demand, a rise in P/D ratio may be caused by a decline in demersal stocks due to overexploitation.

Hence, a positive trend over time in the P/D index may depend both on eutrophication and

overexploitation of resources (Libralato et al., 2004). Nutrient enrichment and overfishing have similar and synergistic effects: a decline in diversity, an initial increase in productivity of benthic/demersal and pelagic food webs, then the progressive dominance of the production system by short-lived, especially pelagic species (Caddy, 1993). In all the areas the ratio between the landings of pelagic and demersal species increased with time, a fact showing that fisheries in these areas are increasingly relying on the smaller, short-lived fishes from the lower part of marine food webs.

It is clear that the small pelagic fish are essential elements of marine ecosystems due to their significant biomass at intermediate levels of the food web, playing a considerable role in connecting the lower and upper trophic levels. Small pelagics are usually considered as forage fish (Tacon & Metian, 2009).

Therefore, fluctuations in small pelagic populations can modify ecosystem structure and functioning and have a major impact on the whole ecosystem. The data show a gradual transition in landings from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish. High exploitation rates have been applied to demersal stocks over the last few decades and particulary in the western Mediterranean. Comparison with the analysis of the multispecies landings shows that the trend of the index is influenced more by the landings of Clupeidae and Engraulidae, which in fact represent more than 60% of the total landings of the Mediterranean area. The analysis also revealed a divergent trend between species most representative

of these classes (*Sardina pilchardus* and *Engraulis encrasicolus*); when the first declines, the latter increases significantly and viceversa. In the last decade the increase in landings of small pelagic fish is probably compounded by increasing competition from the fish meal market due to increasing demands from the aquaculture industry for the production of carnivore fish and shrimps for the high value markets (Tacon & Metian, 2009).

The species considered demersals (although some of them show a pelagic behaviour) represent around 40% of total reported landings in the Mediterranean. In those areas there is an identifiable series of target species as hake (*Merluccius merluccius*), red mullets (*Mullus* spp.), blue whiting (*Micromesistius poutassou*), whiting (*Merlangius merlangus*), anglerfishes (*Lophius* spp.), *Pagellus* spp., bogue (*Boops boops*), picarels (*Spicara* spp.) striped venus (*Chamelea gallina*), *Octopus* spp., cuttlefish (*Sepia officinalis*) and the red shrimp (*Aristeus antennatus*).

Analysis shows that the two environmental variables examined influence the P/D ratio but does not fully explain its trend. The Chl-a and rainfall levels may be at least partly associated with nutrient run-off of the areas. In particular, the associations pointed out between the P/D ratio and the Chl-a index, suggest that the P/D ratio may be a useful indirect index of the level of nutrients available.

The Mediterranean has been globally considered as an oligotrophic sea (Margalef, 1985; Estrada, 1996; Stergiou et al., 1997). The satellite imagery of Chl-a shows a gradual decrease in nutrient which would result in a west to east decrease in productivity, with local exceptions resulting from a north to south productivity gradient due to incoming nutrients
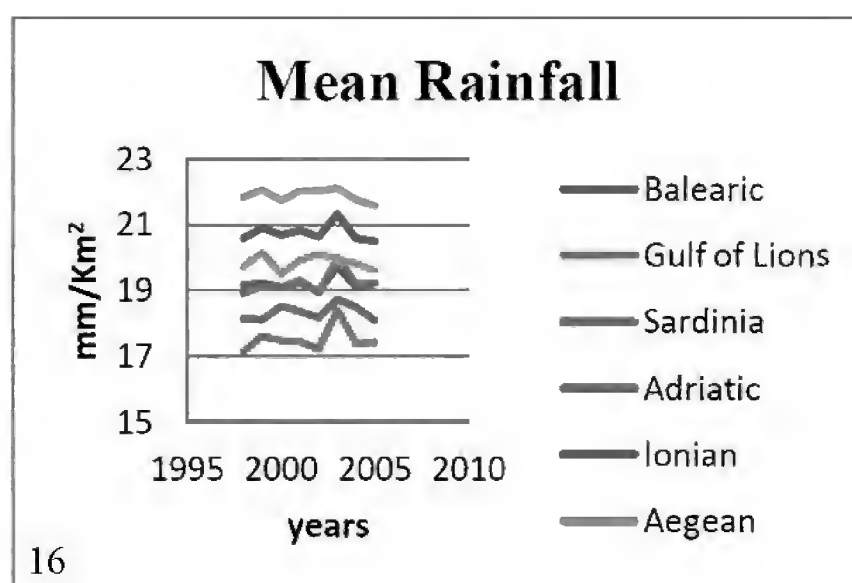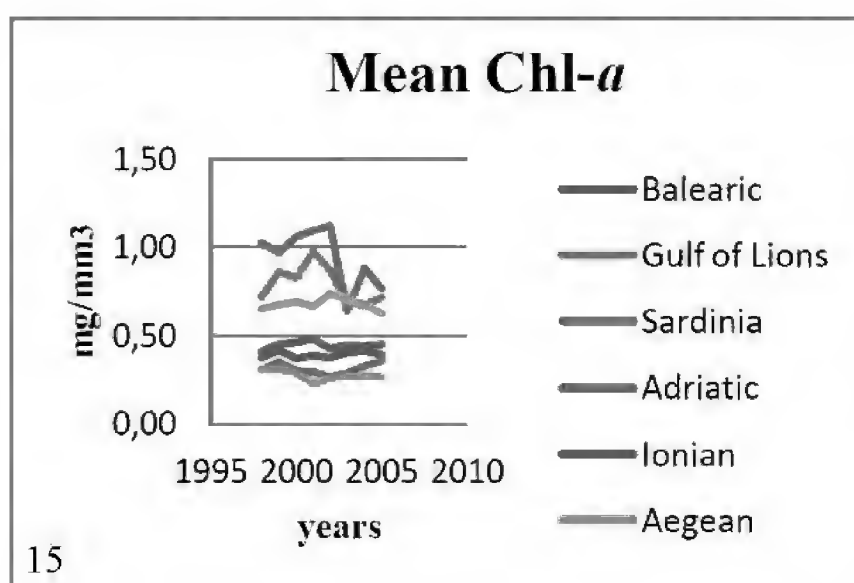

Figure 15. Mean Chlorophylla-a (1970-2005). Figure 16. Mean precipitation (1970-2005).

from rivers as the Rhône in the Gulf of Lions, the Po in Adriatic division and different inflows into the Aegean. In Sardinia division nutrient inputs from land are low and, in the south and east, Mediterranean nutrients have been severely depleted during the eastward flow of surface waters from the Straits of Gibraltar (Murdoch & Onuf, 1972; Caddy & Oliver, 1996).

In Ionian area there is a restricted water exchange across the shallow sill between the Adriatic basins, and this seems to reflect a trophodynamic regime efficiently removing nutrients from the coastal current moving southward from the northern Adriatic (Civitarese et al., 1998). Nutrient levels in the Levant are very low and Chl-*a* concentrations off the coast of Israel are between 1/2 and 1/10 of those for the Sargasso Sea, an area of very low primary productivity (Azov, 1990). Also, river run-off has been substantially reduced since blockage of Nile outflow by the Aswan Dam (Halim et al., 1995).

The lowest P/D ratios occur in the Sardinia, Ionian and Levant divisions and remain below unity for the entire time series. In these areas the fisheries are characterised by fragmented fleets, usually composed by relatively small vessels, use of a large number of landing sites and multi-species landings. The positive index indicates a dominance of pelagic on demersal fish, but values less than 1 suggest that the demersal stocks in these areas are not yet fully exhausted. Also areas where there is a greater presence of zones of upwelling and nutrient inputs, as Balearic and Gulf of Lions, are the ones with the highest values, except for the Adriatic where landings of the class Bivalvia greatly influence the trend of the P/D ratio.

ACKNOWLEDGMENTS

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Diversity and distribution of seaweeds in the Kudankulam coastal waters, South-Eastern coast of India

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ABSTRACT   The macroalgal resources of inter-tidal region of Kudankulam coastal waters are presented in this paper. A total of 32 taxa were recorded in the Kudankulam region: 15 belonging to Chlorophyta, 8 to Phaeophyta and 9 to Rhodophyta. *Ulva fasciata* Delil, *Sargassum wightii* Greville, *Chaetomorpha linum* (O.F. Müller) Kützing, *Hydropuntia edulis* (Gmelin) Gurgel et Fredericq, *Dictyota dichotoma* (Hudson) Lamouroux, *Caulerpa sertulariodes* (Gmelin) Howe, *Acanthophora muscoides* (Linnaeus) Bory de Saint-Vincent and *Ulva compressa* Linnaeus were the commonly occurring seaweeds in the rocky shores and other submerged hard surfaces. The seasonal abundance of seaweeds was studied by submerging wooden test panels in the coastal waters. The seaweed abundance on test panels was high during pre-monsoon and monsoon periods and low in post-monsoon season. In general, an updated checklist and distribution of seaweeds from Kudankulam region of Southeast coast of India is described.

KEY WORDS   macroalgae; benthic community; coastal biodiversity; rocky shores; Indian Ocean.

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INTRODUCTION

Seaweeds are considered as ecologically and biologically important component in the marine ecosystems. Seaweeds make a substantial contribution to marine primary production and provide habitat for nearshore benthic communities (Mann, 1973; Williams & Smith, 2007).

Seaweeds are key space occupiers of rocky shores and interact with other organisms and hence play a key role in overall coastal biodiversity. They are found on rocks in the intertidal zone as a giant underwater forest. It was estimated that about 200 seaweed species support an international economy in primarily phycocolloid (algins, agars, and carrageenans) and food products valued at over billions of U.S. $ 6.2 (Zemke-White & Ohno, 1999).

Seaweeds grow abundantly along the Indian coastline particularly in rocky shore regions; rich seaweed beds occur around Visakhapatnam in the eastern coast, Mahabalipuram, Gulf of Mannar, Tiruchendur, Tuticorin and Kerala in the southern coast; Veraval and Gulf of Kutch in the western coast; Andaman and Nicobar Islands and Lakshadweep (Umamaheswara Rao, 1967; Silva et al., 1996; Sahoo, 2001).

The seaweed resources are also abundant around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu and Chilka in Orissa. About 841 taxa of marine algae were found in both inter-tidal and deep water regions of the Indian coast (Oza & Zaidi, 2001).

Seaweeds are under threat in developing countries, where they are being disturbed by a variety of human activities. Increasing concern on destruction of seaweed resources and alterations in the diversity of various life forms makes it necessary the studies on the taxonomy and species diversity for a better management of marine algae. Although systematic studies on marine algae and their distribution are

known from different coastal parts of India, not much published informations are available about the seaweeds of Kudankulam coastal waters, hence the distribution and diversity of seaweed species of Kudankulam coast is presented in this paper. Such a study in this region can be of great importance due to the emerging mega Nuclear Power Project.

Ecological survey of water bodies around a power plant is an important endeavour both from the environmental and the operational point of view. The release of warm water to the receiving water body is of concern due to the long and short-term impact on the flora and fauna.

MATERIALS AND METHODS

The investigation was carried out at Kudankulam (8° 9' 5" N and 77° 39' 59" E), Gulf of Mannar in the southeast coast of India (Fig. 1). The study area is situated on the distal end of Gulf of Mannar Biosphere Reserve. The rocky shore of Kudankulam inhabits an astonishing biodiversity, representing nearly almost all the invertebrate phyla and urochordates. Hard rocky bottom of this area greatly supports the algal diversity and provide suitable shelter and feeding ground for grazers. Seasons at Kudankulam may be classified into pre-monsoon (June-September), monsoon (October-January), and post-monsoon (February-May).

Field surveys were undertaken to the selected sampling stations of the Kudankulam region over a period of three years from 2003 to 2006. The algal samples were collected in every season during the study period by detaching a portion from the seaweed bed, kept in polythene bags with fresh seawater, transported to the laboratory and fixed in 4% formaldeyde for further studies.

The seaweeds were identified using the taxonomic keys provided by Umamaheswara Rao (1987), Desikachary et al. (1990, 1998) and Krishnamurthy (1999), and the nomenclature was updated using Appeltans et al. (2012).

The seasonal distribution of seaweeds was studied by submerging test panels for a period of one year from June 2003 to May 2004. Test panels made from teak wood with a size of 10 x 10 x 2 cm were vertically placed in a suitably designed wooden raft with grooves in such a way so as to keep a 10 cm distance between panels.

The raft with panels (in replicate, n = 6) was suspended at 2 m depth in the coastal waters using floats and sinkers. Panels were suspended during the first week of a season and retrieved during the last week of that season so as to keep the panels for 110 days in coastal waters. Each panel was studied for the seaweed species composition and biomass. The total and the differential biomass (wet weight) of the seaweeds were estimated after carefully scrapping them from the panels and weighing them.
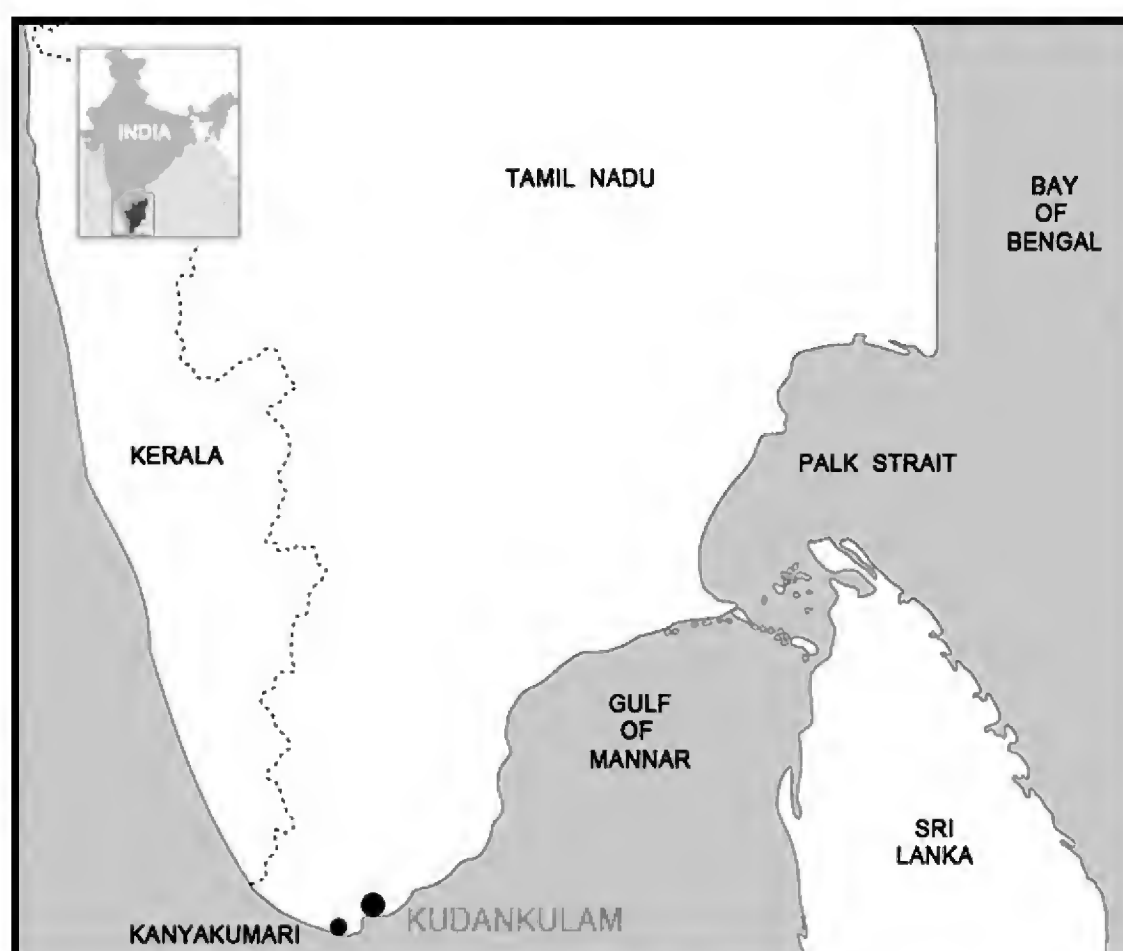

Figure 1. Map showing the study area: Kudankulam, Gulf of Mannar in the southeast coast of India.

RESULTS

A total of 32 seaweed taxa were collected from the Kudankulam region (Table 1). The Chlorophyta prevailed with 15 taxa followed by Rhodophyta (9 taxa) and Phaeophyta (8 taxa).

Ulva fasciata Delile, *Sargassum wightii* Greville, *Chaetomorpha linum* (O.F.Müller) Kützing, *Gracilaria edulis* (Gmelin) Gurgel et Fredericq, *Dictyota dichotoma* (Hudson) Lamouroux, *Cau-*

lerpa sertulariodes (Gmelin) Howe, *Acanthophora muscoides* (Linnaeus) Bory de Saint-Vincent and *Ulva compressa* Linnaeus were the commonly found seaweeds in the rocky shores and other submerged hard surfaces.

Ulva fasciata is the common green alga inhabiting the rocky shores of this region. During the monsoon season (October-January), *Ulva fasciata* forms thick mats covering the entire rocky substratum (Fig. 2).

CHLOROPHYTA	*Stoechospermum polypodioides* (Lamouroux) Agardh, 1848

Order Ulvales
Family Ulvaceae
    Ulva compressa Linnaeus, 1753
    Ulva intestinalis Linnaeus, 1753
    Ulva fasciata Delile, 1813
    Ulva lactuca Linnaeus, 1753
    Ulva reticulata Forsskål, 1775
	Order Ectocarpales
	Family Scytosiphonaceae
	    Colpomenia sinuosa (Mertens ex Roth) Derbès et Solier, 1851

Order Cladophorales
Family Cladophoraceae
    Chaetomorpha antennina (Bory de Saint-Vincent) Kützing , 1847
    Chaetomorpha linoides Kützing, 1847
    Chaetomorpha linum (O.F. Müller) Kützing, 1845
	Order Fucales
	Family Sargassaceae
	    Sargassum ilicifolium (Turner) Agardh, 1820
	    Sargassum wightii Greville, 1848
	
	RHODOPHYTA

Order Bryopsidales
Family Caulerpaceae
    Caulerpa peltata Lamouroux, 1809
    Caulerpa scalpelliformis (Brown ex Turner) Agardh, 1817
    Caulerpa sertularioides (Gmelin) Howe, 1905
    Caulerpa racemosa (Forsskål) Agardh , 1873
	Order Gracilariales
	Family Gracilariaceae
	    Hydropuntia edulis (Gmelin) Gurgel et Frdricq, 2004
	    Gracilaria corticata (Agardh) Agardh, 1852
	    Gracilaria debilis (Forsskål) Børgesen, 1932

Family Halimedaceae
    Halimeda macroloba Decaisne, 1841
    Halimeda opuntia (Linnaeus) Lamouroux, 1816
	Order Gigartinales
	Family Solieriaceae
	    Sarconema filiforme (Sonder) Kylin, 1932

Order Siphonocladales
Family Valoniaceae
    Valoniopsis pachynema (Martens) Børgesen, 1934
	Family Cystocloniaceae
	    Hypnea valentiae (Turner) Montagne, 1841

PHAEOPHYTA	Family Phyllophoraceae *Ahnfeltiopsis densa* (J.Agardh) Silva et De Cew,1992

Order Dictyotales
Family Dictyotaceae
    Dictyota dichotoma (Hudson) Lamouroux, 1809
    Padina pavonica (Linnaeus) Thivy, 1960
    Padinia antillarum (Kützing) Picone, 1886
    Padina gymnospora (Kützing) Sonder, 1871
	Order Ceramiales
	Family Rhodomelaceae
	    Acanthophora muscoides (Linnaeus) Bory de Saint-Vincent, 1828
	    Palisandra perforata (Bory de Saint-Vincent) Nam, 2007
	
	Order Corallinales
	Family Corallinaceae
	    Amphiroa sp.

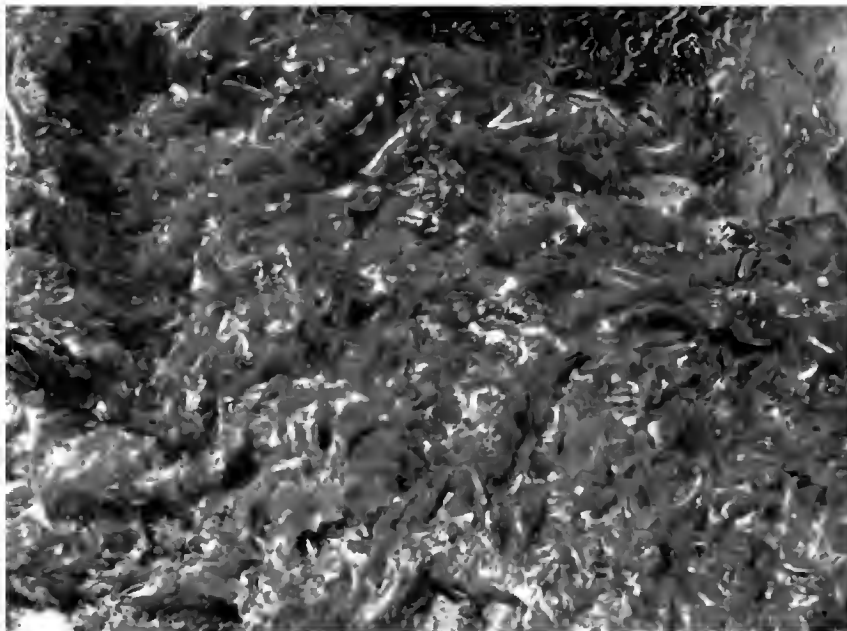Table 1. Checklist of seaweed taxa found in Kudankulam coastal waters.

Figure 2. Intertidal rocky reef covered by *Ulva fasciata* in Kudankulam coastal waters.

Figure 3. Growth of *Ulva fasciata, Caulerpa racemosa, Sargassum wightii* and *Gracilaria corticata* in the rocky shores of stydy area.

Chaetomorpha linum, and *Caulerpa sertulariodes* are the other dominant green seaweeds taxa observed during this period of study.

The brown seaweeds (Phaeophyta) are represented by 8 taxa and *Sargassum wightii* is the dominant one. *Dictyota dichotoma* and *Padina antillarum* (Kützing) Picone are also abundantly observed on the intertidal rocky reefs. A rich growth of *Sargassum* sp.pl. was observed during pre-monsoon and monsoon months (Fig. 3). *Sargassum* sp. pl. was harvested during October-December period by the local people. *Colpomenia sinuosa* (Mertens ex Roth) Derbès et Solier was commonly observed on the artificial substrata submerged in the seawater.

Rhodophyta of the Kudankulam coastal waters consisted of 9 taxa. *Gracilaria corticata* (Ag.) Agardh, *Hydropuntia edulis* (Gmelin) Gurgel et Fredericq, and *Acanthophora muscoides* (Linnaeus) Bory de Saint-Vincent were the dominant red seaweeds observed during this study period. *Amphiroa* sp. and *Hypnea valentiae* (Turner) Montagne were also commonly observed on the rocks. *Gracilaria* sp.pl. were abundantly observed during May-October period. *Acanthophora muscoides* and *Hypnea valentiae* were abundant during November-January period on the rocky shores.

The test panels immersed during June 2003 and examined at the end of September 2003 (pre-monsoon) showed a total algal biomass value of 13.14 ± 2.9 g/dm^2 (Table 2). The macro-algal community of the panels submerged during this period was dominated by *Ulva fasciata* (5.3 ± 1.7 g/dm^2) and *Ulva compressa* (3.18 ± 0.9 g/dm^2) (Table 2). *Hydropuntia edulis* (2.5 ± 0.78 g/dm^2) was also observed as one of the dominant groups in this panel

series. *Sargassum wightii*, *Padina antillarum* and *Hypnea valentiae* were also observed. The panels exposed during the monsoon season (October-January) showed a biomass value of 19 ± 2.3 g/dm^2, dominated by *Ulva compressa* (4.7 ± 0.9 g/dm^2) and *Acanthophora muscoides* (3.8 ± 0.71 g/dm^2).

The biomass of *Ulva fasciata* Delil on this panel series was 1.92 ± 0.72 g/dm^2, while *Hypnea valentiae* recorded a very low biomass value of 0.6 ± 0.09 g/dm^2. *Sargassum wightii* was also observed on the panels with a biomass of 0.81 ± 0.12 g/dm^2.

The panels submerged during the post-monsoon season (February-May 2004) showed a seaweed biomass of 6.3 ± 1.2 g/dm^2. *Hydropuntia edulis*, showed a biomass value of 1.87 ± 0.087 g/dm^2 followed by *Acanthophora muscoides* (1.71 ± 0.48 g/dm^2). The biomass of *Ulva compressa* on post-monsoon panels was 1.6 ± 0.2 g/dm^2 (Table 2). *Ulva fasciata* and *Hypnea valentiae* were also observed on the panels submerged during post-monsoon season.

DISCUSSION

Studies on the diversity and distribution of seaweeds in Indian waters were carried out by several authors (Untawale et al., 1989; Kalimuthu et al., 1995; Jayachandran & Ramaswamy 1997; Kaliaperumal & Kalimuthu, 1997; Stella Roslin et al., 1997; Selvaraj & Selvaraj, 1997; Mohammed et al., 1999; James et al., 2004; Krekar, 2004; Rath & Adhikary, 2006). Southeast coast of India is a unique marine habitat characterized by a high biodiversity. Results of the present study indicate the occurrence of 32 seaweed taxa in the Kudanku-

	Pre-monsoon season	Monsoon season	Post-monsoon season
Total algal biomass	13.14±2.90	19.00±2.30	6.30± 1.20
Ulva fasciata	5.30±1.70	1.92±0.72	0.70±0.04
Ulva compressa	3.18±0.90	4.70±0.90	1.60±0.20
Hydropuntia edulis	2.50± 0.78	4.70±0.90	1.87±0.09
Acanthophora muscoides	---	3.80±0.71	1.71±0.48
Sargassum wightii	---	0.81±0.12	---
Hypnea valentiae	---	0.60±0.090	---

Table 2. Biomass of seaweeds settled on the wooden test panels submerged in pre-monsoon, monsoon and post-monsoon season period at Kudankulam coast. The wet biomass values are expressed as g/dm^2. Missing values (---) indicates very low biomass values in that season.

lam coastal waters; most of the seaweeds such as *Sargassum wightii*, *Ulva fasciata*, *Gracilaria corticata* and *Chaetomorpha linum*, are abundantly observed on the rocks during the pre-monsoon (June-September) and monsoon months (October-January). The richness of seaweed resources is due to the intertidal rocky reefs available in the Kudankulam region. The seaweed flora observed in the present study is similar to that reported from the nearby Tiruchendur coast (Chennubhotla et al., 1991).

Marine ecologists have a long history of using artificial substrate and habitats to test hypothesis about sessile plants and animals (Osman, 1977; Sutherland & Karlson, 1977). In this study, settlement panels were used to analyse the seasonal distribution of macroalgal communities. The seaweed biomass on test panels was high during pre-monsoon and monsoon seasons. In an earlier study (Satheesh & Wesley, 2007), we have reported that *Gracilaria* sp., *Enteromorpha* sp., and *Ulva* sp., showed dense settlement during pre-monsoon and post monsoon months on test panels.

The observed pattern of seasonal distribution is likely to be related to the life history of the alga, particularly the dispersal abilities of its spores. The supply from macroalgal propagule may influence the abundance of algae in littoral habitats (Worm et al., 2001). As the test panels provide limited space for the settlement of marine organisms including seaweeds, the seasonal biomass of only a few species could be observed in this study.

Gradual rise in the anthropogenic influence, impact of the possible thermal discharge from the emerging nuclear power station and the indiscriminate collection of algae (mostly *Sargassum* sp.) may be the cause of concern for the biodiversity of algal species at Kudankulam coast. Both frond bleaching and cell plasmolysis of algae were observed in thermal effluent discharge areas (North, 1969; Lobban et al., 1985).

These negative effects may reduce the survival and growth of seaweeds, resulting in extensive reductions in the number of species of marine algae (Wood & Zieman, 1969).

The present study could be useful as new baseline record for future biomonitoring studies in this coast. Further systematic studies on the seaweed resources may provide useful data for the conservation of marine algal resources in this region.

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Carabus (Eurycarabus) faminii Dejean, 1826 (Coleoptera, Carabidae) in Sicily: distribution and taxonomic considerations with description of a new taxon

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ABSTRACT   The study of large series from many localities from all over Sicily of *Carabus (Eurycarabus) faminii* Dejean, 1826 confirmed that in Sicily live two different subspecies. After examination of the holotypus of *C. faminii* we found that *C. faminii sabellai* Sparacio, 2007 is a synonym of the nominal form widespread in south-east part of Sicily. The western subspecies is described in this paper.

KEY WORDS   Carabidae; *Carabus faminii*; new subspecies; new synonym; Sicily.

INTRODUCTION

Two subspecies of *Carabus (Eurycarabus) faminii* Dejean, 1826 are reported to Sicily: the nominal subspecies, widespread in the western provinces (Turin et al., 1993, 2003; Taglianti Vigna, 1993; Lorenz, 1998; Brežina, 1999; Bousquet et al., 2003; Vigna Taglianti et al., 2002, Deuve, 2004; Sparacio, 2007) and the ssp. *sabellai* Sparacio, 2007 reported to the south-eastern ones (Erei Mountains).

Two other subspecies are widespread in the Maghreb: ssp. *lucasi* Gaubil, 1849 and ssp. *numidicus* Castelnau, 1835 (Casale et al., 1982; Culot, 1985; Ghiretti, 1996).

As part of a larger study on *Carabus faminii* in Sicily we examined the holotypus of the species described by Dejean in 1826 observing that it is precisely identified with the recently described subspecies from Erei Mountains. Taking into account this consideration the form collected since XIX Century in the western provinces of Palermo, Trapani and West Agrigento, would result without a name and is described in the present paper. Moreover we also review the distribution of the two *Carabus faminii* populations in Sicily in the light of some recent findings.

ACRONYMS. The materials used for this study are deposited in the following Museums and private collections: Vittorio Aliquò, Palermo, Italy (CA); Marcello Arnone, Palermo, Italy (CMA); Michele Bellavista, Palermo, Italy (CB); Muséum National d'Histoire Naturelle, Paris (MNHN); Museo di Storia Naturale di Niscemi, Caltanissetta, Italy (CMN); Ivan Rapuzzi, Prepotto, Udine, Italy (CR); Marcello Romano, Capaci, Palermo, Italy (CMR); Ignazio Sparacio, Palermo, Italy (CS); Roberto Torrisi, Motta Sant'Anastasia, Catania, Italy (CT).

Carabus (Eurycarabus) faminii faminii Dejean, 1826

EXAMINED MATERIAL. Holotypus (MNHN); Monti Erei (Enna): Monte Rossomanno, 4 males and 3 females (CS; CR); Sughereta di Niscemi (Caltanissetta), 1 male (CMN); Licodia Eubea (Catania), Bosco Vaito (CT); Agrigento, 4 males and 3 females (CR; CS); Agrigento, Valle dei Templi, 1 female (CMA); Piazza Armerina, Aidone (Enna), 1 male and 2 females (CR).

HOLOTYPUS OF *C. faminii* Dejean, 1826. The holotypus (Figs. 1, 4) is a pinned specimen, length of 21.5 mm, with the following original labels: red

label with the written "HOLOTYPE"; label with the written EC42; label with the symbol "♂"; label with the written "Ex Musaeo Chaudoir"; label with the written "Carabus famini Dejean".

Body black, polished, lateral margins of pronotum and elytra slightly red-purple. Head of normal shape, smooth front, neck faintly punctulate and rugulose; convex eyes, frontal furrows narrow, extended to the anterior border of eyes, clypeus small, labrum bilobed; antennae thin and short, surpassing with three segments the base of elytra. Apical segment of palpi strongly widened, the maxillary ones are axe-shaped.

Pronotum transverse, sides regularly rounded, maximum width in the anterior third, rounded front margins, hind angles of pronotum rounded and large, thin and complete median sulcus, surface finely punctured.

Elytra short, oval, very convex; rough surface with irregular sculpture; primary intervals forming rows of short tubercles interrupted by foveae; secondary and tertiary intervals confused in a large, smooth and flat area. Legs short and robust, femurs wrinkles on both surfaces.

VARIABILITY. The examined specimens from South-Eastern Sicily are morphologically related to the holotype of C. *faminii* Dejean, 1826 described above, size ranges from 20 mm to 23 mm, the lateral margins of elytra and pronotum are sligthly colored, completely absent in some specimens.

The aedeagus of a specimen from Rossomanno Mount (it was not possible to extract the aedeagus from the holotype) was described and figured by Sparacio (Sparacio, 2007).

Females are more convex with rounded elytra, length ranges from 21 mm to 23 mm.

BIOLOGY AND DISTRIBUTION. C. *faminii faminii* was collected under stones and debris of *Pinus* and *Eucalyptus* reforestation and oak bushes.

The nominal subspecies is distributed in southeastern provinces (Fig. 7). In the map are reported the following localities: Licodia Eubea (Torrisi, 2010), Agrigento, Pachino (Magistretti, 1962, 1965) in addition to Erei Mountains (Rossomanno Mount and Aidone) and Sughereta di Niscemi.

COMPARATIVE NOTES. The holotypus of C. *faminii* Dejean, 1826 is identified to the spp. *sabellai*

(see Sparacio, 2007). Under this consideration it is necessary to establish the following synonymy:

Carabus (Eurycarabus) faminii faminii Dejean, 1826

= *Carabus (Eurycarabus) faminii sabellai* Sparacio, 2007 n. syn.

Carabus (Eurycarabus) faminii romanoi n.ssp.

EXAMINED MATERIAL. Holotypus male, Godrano (PA), 25.XI.1978, legit I.Sparacio (CR); Paratypi: Bosco Ficuzza (PA), loc. Valle Maria, 7.I.1973, 1 male (CMR); Triscina (TP), 23.IV.1973, 1 male and 1 female (CMR); Mazara del Vallo (TP), 17.XI.1974, 1 female (CMR); Piana degli Albanesi (PA), Monte Maganoce, 4.I.1974, 1 female (CMR); idem, 11.XII.1974, 1 male and 1 female (CMR); idem, 11.I.1976, 1 female (CMR); Godrano (PA), 3.I.1975, 1 male and 1 female (CMR); idem, 11.I.1976, 1 male (CMR); idem, XI.1976, 1 male and 2 females (CMR); idem, 3.I.1979, 1 male and 1 female (CMR); idem, 23.XI.1979, 1 male and 2 females (CMR); idem, 16.I.1980, 1 female (CMR); idem, 23.I.1980, 1 male and 2 females (CMR); idem, 1.II.1981, 2 males (CMR); idem, 30.XI.1980, 1 male and 3 females (CMR); idem, 4.I.1989, 1 male and 2 females (CMR); idem, 20.XII.1992, 1 female (CMR); Lago Rubino (TP), 6.II.1980, 2 males (CMR); Godrano (PA), 25.XI.1978, 1 male and 1 female (CA); idem, 21.X.1979, 2 males (CA); idem, 9.XII.1979, 3 males (CA); idem, 16.I.1980, 2 females (CA); idem, 20.I.1980, 1 male (CA); idem, 2.III.1980, 1 female (CA); idem, 2.III.1980, 1 male (CA); idem, 10.I.1993, 1 female (CA); idem, 12.X.1996, 2 females (CA); idem, 23.II.2003, 1 female (CA); Campobello di Mazara (TP), Cave di Cusa, 31.XII.1989, 1 male and 1 female (CA); Bosco Ficuzza (PA), 28.I.1989, 2 males (CA); Foce Fiume Belice (TP), 17.IV.1988, 1 female (CA); idem, 21.XI.1992, 1 male and 1 female (CA); idem, 16.XII.1992, 1 male (CA); Lago Scanzano (PA), 20.III.2005, 1 male and 1 female (CA); Godrano (PA), 25.XI.1978, 1 male and 1 female (Coll. IS); idem, 30.XI.1996, 2 males and 1 female (CS); Foce Fiume Belice (TP), 10.VI.1981, 2 females (CS); idem, 17.IV.1993, 2 males (CS); Bosco Ficuzza (PA), 28.I.1989, 2 males and 2 females (CS); idem, 31.XII.1989, 1 female (CS); idem, 28.XI.1993, 2 males (CS); idem, 5.XII.1993, 1 male and 1 female (CS); idem, 30.XI.1996, 1 male (CS); idem, 13.XI.2001, 1 male and 4 females
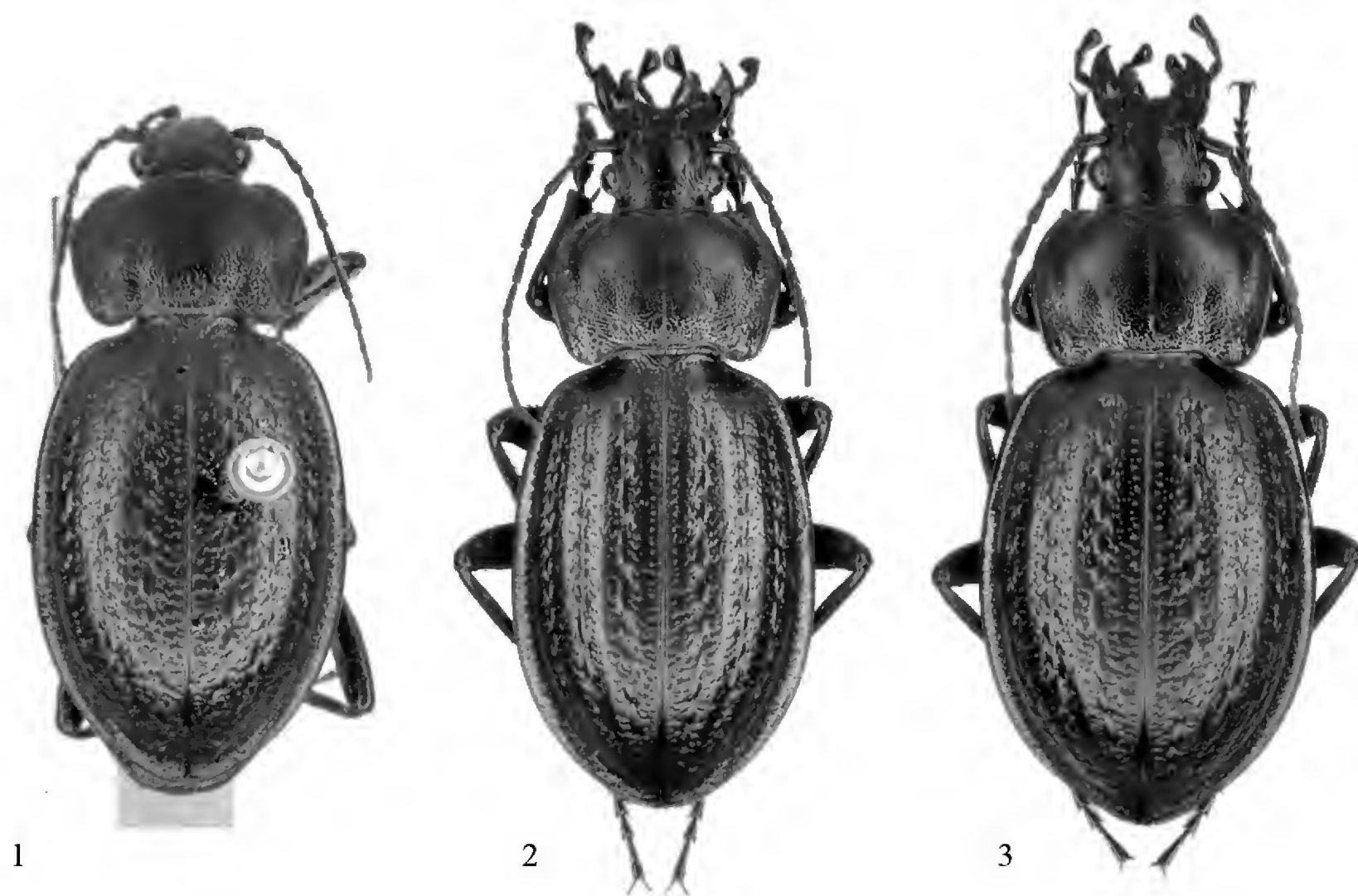
Figure 1. *C. faminii faminii* holotypus. Figure 2. *C. faminii romanoi* n. ssp. holotypus. Figure 3. *C. faminii romanoi* n. ssp. paratype female, Sicilia, Bosco Ficuzza (PA), XII.2010, I. Rapuzzi & L. Caldon leg. (CR), lenght 26 mm.

(CS); Campobello di Mazara (TP), Cave di Cusa, 31.XII.1988, 1 male and 2 females (CS); Bosco Ficuzza (PA), 8.II.2009, 2 males and 2 females (CS); Bosco Ficuzza (PA) 8.XII.1978, 1 male and 1 female (CB); idem, 23.XI.1979, 1 male (CB); idem, 27.XII.2008, 1 male and 1 female (CB); Piana Albanesi (PA), I.1975, 1 female (CR); Bosco Ficuzza (PA), XII.1980, 1 male (CR); idem, 11.II.1989, 1 female (CR); idem, 6.XII.1992, 1 male (CR); idem, XII.2009, 1 male and 1 female (CR); idem, XII.2010, 7 males and 8 females (CR); Corleone (PA), 30.XI.1988, 1 female (CR); Foce Fiume Belice (TP), 21.XI.1992, 1 female (CR); Campobello di Mazara (TP), 20.X.1985, 1 female (CR); Godrano (PA), XII.2009, 7 males and 5 females (CR); idem, XI.2010, 3 males and 8 females (CR); Godrano, 25.XI.1978, 1 males (CMA); idem, 21.X.1979, 2 males (CMA); idem, 9.XII.1979, 3 males (CMA); idem, 16.I.1980, 2 males (CMA); idem, 20.I.1980, 1 male (CMA); idem, 25.XI.1992, 1 male (CMA); idem, 10.I.1993, 1 female (CMA); idem, 12.X.1996, 2 females (CMA); idem, 23.II.2003, 1 female (CMA); Bosco Ficuzza, 28.I.1989, 2 males (CMA); Campobello di Mazara,

Cave di Cusa, 31.XII.1988, 1 male and 1 female (CMA); Foce F. Belice, 17.IV.1988, 1 female (CMA); idem, 21.XI.1992, 1 male and 1 female (CMA); idem, 16.XII.1992, 1 male (CMA); Bosco Ficuzza, Lago Scanzano, 20.III.2005, 1 male and 1 female (CMA).

DESCRIPTION OF HOLOTYPUS MALE. Length including mandibles: 24 mm, maximum width of elytra: 10 mm. Body black, the margins of pronotum and of the edge of elytra with purple. Shiny above (Fig. 2).

Head of normal size, surface with punctures more evident at the base and sides, front and disc almost perfectly smooth; supra-antennary ridge deep and split. Eyes very salient, perfectly hemispherical. Short antennae extending with 2.5 antennomeres beyond pronotal base. Apical segment of palpi strongly widened, axe-shaped; labial palp bisetose. Pronotum very transverse as wide as elytra, slightly convex, very wide at base, maximum width at the middle; sides regularly rounded and bent upwards at the basal angles. Hind angles of pronotum

very long and widely rounded; basal depression broad and deep. Pronotal disc slightly rough, sides and base with irregular punctures.

Elytra oval elongated, convex, maximum width beyond the half, shoulders angulate, sides regularly rounded. Heterodynamic elytral sculpture: primary intervals in form of short catenate rows, interrupted by foveae with metallic lustre; secondary and tertiary intervals fused in a single intermediate zone raised as or more than primary intervals. Legs short of normal size.

Aedeagus (Figs. 5, 6) characteristic of the species but a little more developed and with shorter apex than *C. faminii faminii*.

VARIABILITY. The length of the body ranges from 23 mm to 28 mm. The color of the margins of the pronotum and the edge of the elytra is more frequently red-violet or purple, rarely green or golden green. Labial palp are disetose or trisetose. Shape of pronotum and elytral sculpture are very little variable.

ETIMOLOGY. We are honoured to dedicate this new subspecies to our friend Marcello Romano (Capaci, Palermo, Italy) entomologist and connoisseur of Sicilian biodiversity.

BIOLOGY AND DISTRIBUTION. *C. faminii romanoi* n.ssp. was found under stones and debris in various types of environments: i.e. dune system, stony ground, undergrowth of woodlands or natural reforestation, even degraded, generally down to 800 m above sea level.

The species survives with small population very isolated and endangered by the loss of original vegetation due to urbanisation and agriculture (authors' observations, Ragusa, 1883; Aliquò, 1970; Aliquò & Castelli, 1991). According to Palumbo (1892) the species was common in Selinunte area. In Sicily *C. faminii romanoi* n. ssp. is known only from the Western provinces: Palermo, Trapani and Western part of Agrigento (Fig. 7). It is reported for several localities.

C. faminii romanoi n.ssp. (*C. faminii* sensu Auctores) is reported from: Monte Pellegrino, Palermo (Ghiliani, 1839), Termini Imerese (Calcara, 1842), Palermo, Agrigento (Rottenberg, 1870-71), Favorita near Palermo (Ragusa, 1874), Santa Ninfa and Prizzi (De Stefani & Riggio, 1882), Segesta, Castelvetrano and Favorita near Palermo (Ragusa, 1883), Castelvetrano, Selinunte (Palumbo, 1890, 1892), Palermo, Prizzi and Castelvetrano (Vitale, 1912; Luigioni, 1929), Palermo: Passo di Rigano (Luigioni & Tirelli, 1912), Palermo, Castelvetrano (Magistretti, 1962), Marsala (Magistretti, 1965), Monte Pellegrino (Aliquò, 1970), Piana degli Albanesi, Bosco Ficuzza and Rocca Busambra (Riggio & Massa, 1974), provincie di Agrigento, Trapani and Palermo (Casale et al., 1982; Du Chatenet, 1986, 2005; Sparacio, 1995), contrada Tonnarella and borgata Costiera (Mazara del Vallo), Capo Granitola, Cave di Cusa, Partanna (Aliquò & Castelli, 1991), Prizzi, Castelvetrano, Salemi (Facchini & Baviera, 2004), Agrigento, Realmonte (Casale et al., 2005).

COMPARATIVE NOTES. *C. faminii romanoi* differs from *C. faminii faminii* for the following characters: larger body size; wider and livelier coloration on lateral margins of elytra and pronotum; stronger head; eyes more prominent; antennae shorter and stronger; larger pronotum with a wider base; longer and less convex elytra; elytral intervals strongly convex, raised and regular; stronger legs.
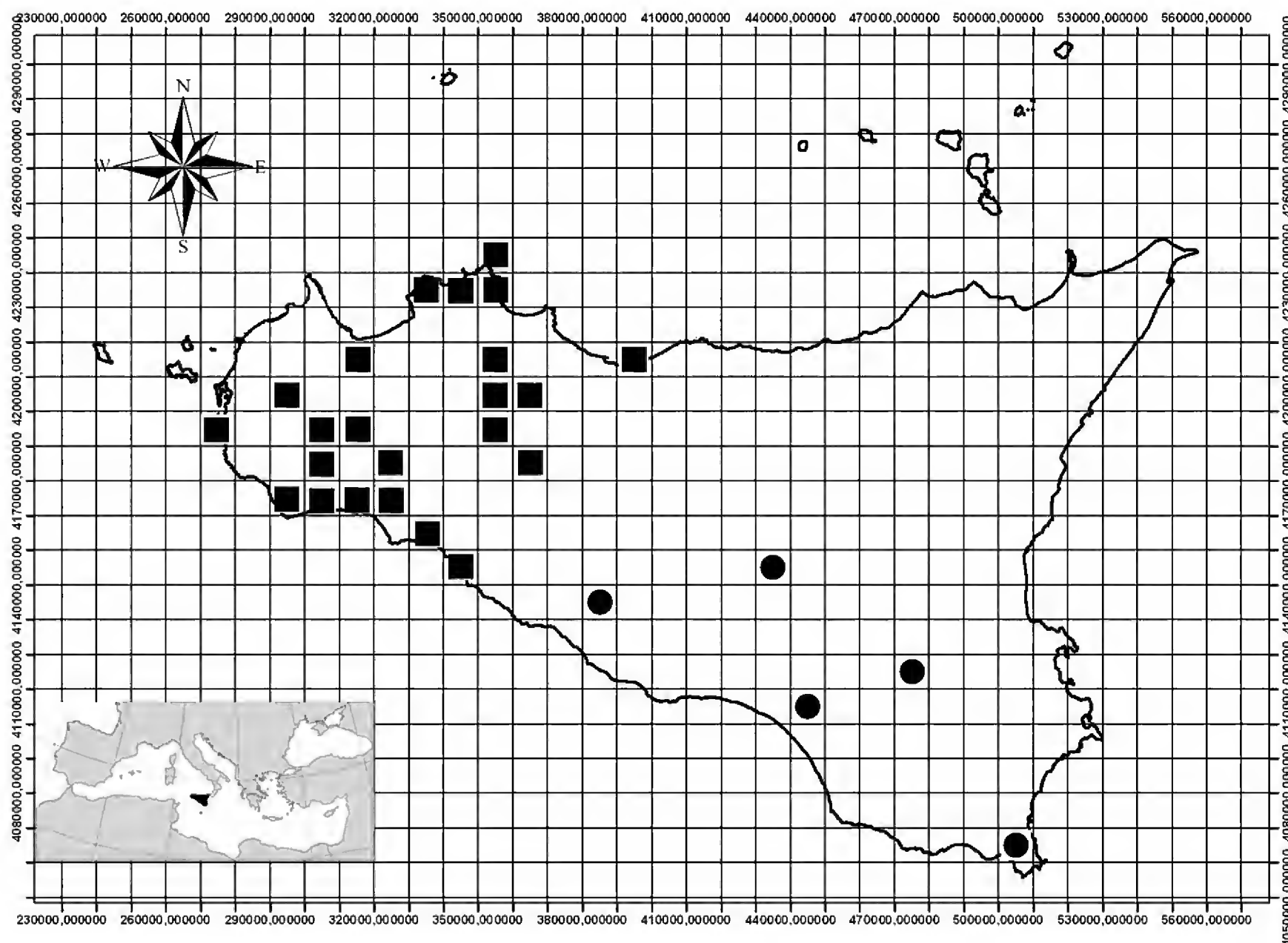

Figure 4. *C. faminii faminii* holotypus, head and pronotum.
Figure 5. *C. faminii romanoi* n. ssp. aedeagus frontal view.
Figure 6. idem, lateral view.

Figure 7. Geographic distribution of *C. faminii* in Sicily: circles=*C. faminii faminii*; squares=*C. faminii romanoi* n. ssp.

CONCLUSION

In a recent paper one of the authors (Sparacio, 2007) correctly pointed out that *C. faminii* in Sicily includes two different subspecies.

The study of new *C. faminii* populations and the examination of the holotypus, described generically of "Sicily", allowed us to better understand the spread of this species in Sicily. The populations inhabiting the south-east of Sicily (the provinces of Enna, Caltanissetta, Siracusa, Ragusa, southern Catania and the eastern part of Agrigento) belong to the nominative subspecies, whereas the western populations (Province of Trapani, Palermo and Agrigento West) are attributed to *C. faminii romanoi* n. ssp.

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Lurifax vitreus Warén & Bouchet, 2001 (Gastropoda, Orbitestellidae), a new record for deep waters of the Tuscan Archipelago (Tyrrhenian Sea, Italy)

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ABSTRACT   We record a finding of one perfect adult, one young specimen, and other two no-well conserved adults of *Lurifax vitreus* Warén & Bouchet, 2001 (Gastropoda, Orbitestellidae) coming from deep waters of Tuscan Archipelago.

INTRODUCTION

Lurifax vitreus Warén & Bouchet, 2001 was described as a species belonging to the fauna of the resurgence of hot and cold deep sea waters.

The several specimens found came from a very wide distribution area, ranging from the Atlantic ocean ridge hydrothermal vents to the cool "seeps" off New Zealand, with a bathymetry between 850 and 1800 meters (Warén & Bouchet, 2001).

The "cold seep" and "hydrotermal vent" are structures present on the ocean seabeds, supporting biomes completely independent from solar energy. They form as a result of volcanic activity on the ocean floor: the water seeps through cracks in the crust becoming super-heated in contact with magma, being able to reach temperatures of 400 ° C, and then goes back getting into the ocean floor (Pérès & Picard, 1964).

In addition to the discoveries that led to the description of *Lurifax vitreus*, we include the findings of a specimen from the coast of Lazio (-600 Terracina: Ardovini & Cossignani (1999, sub *Antimargarita* sp.) and another adult of the same region of Lazio (Smiriglio & Mariottini, 2002) probably coming from the facies CB at a depth of 450-600 meters.

MATERIALS AND METHODS

The shells reported by this note come from the cleaning of commercial fishing nets of trawlers operating in waters off Tuscany in September 2003. The debris was collected at a depth of 470 m.

Examined Material.
Family Orbitestellidae Iredale, 1917
Genus *Lurifax* Warén & Bouchet, 2001
Lurifax vitreus Warén & Bouchet, 2001

Tuscan Archipelago, Capraia Island, 1 adult shell devoid of soft parts, 1 juvenile shell devoid of soft parts, 2 remnants of adult shells.

DISCUSSION AND CONCLUSIONS

In addition to what already reported by the authors on the occurrence of *Lurifax vitreus* in the "Hydrotermal vents and cold seeps" facies and in the White Coral facies (reported as facies CB), we report the discovery of the species in question for the biocenosis of bathyal sludge (reported as bio-

Figure 1. *Lurifax vitreus*, adult specimen, height 4 mm.
Figure 2. *Lurifax vitreus*, juvenile specimen, height 2.5 mm.

cenosis VB); this assertion is further reflected in the discovery, in the same debris, of species typical of the biocenosis "VB", viz. *Addisonia excentrica* (Tiberi, 1855), *Aporrhais serresianus* (Michaud, 1828), *Dentalium agile* (M. Sars in GO Sars, 1872), *Benthonella tenella* (Jeffreys, 1869), *Abra longicallus* (Chess, 1835).

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A new species of genus *Laubuca* Bleeker, 1860 cyprinid fish from Bangladesh (Cypriniformes, Cyprinidae)

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ABSTRACT   A new species of cyprinid fish (Cypriniformes, Cyprinidae), *Laubuca brahmaputraensis* n. sp. from Brahmaputra River, Bangladesh, is described. This species is distinguished from other species of genus *Laubuca* Bleeker, 1860 by the combination of the following characters: lateral line scales comprising 31-32 + 1-2 scales, transverse line scales of ½6-½7/ 1 / 2½ - 3½ scales, body depth ranging from 25.1 to 29.3 % Standard length (SL), pelvic fin not reaching beyond the anus, anal fin with 3 unbranched rays and 19½-20½ branched rays, black blotch above the pectoral fin base and no tubercles on lower jaw.

KEY WORDS   *Laubuca*; Cyprinidae; Brahmaputra River; Bangladesh; new species.

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INTRODUCTION

Freshwater fishes genus *Laubuca* Bleeker, 1860 (Pisces, Cypriniformes, Cyprinidae) has been reported for Indian subcontinent and Indo-Australian archipelago (Hamilton, 1822; Weber & de Beaufort, 1916; Smith, 1931; Menon, 1952; Silas, 1958; Deraniyagala, 1960; Pethiyagoda et al., 2008).

Currently the genus *Laubuca* comprises eight valid species: *L. caeruleostigmata* Smith, 1931 from Thailand; *L. laubuca* (Hamilton, 1822) widely distributed in Indian subcontinent and Indo-Australian archipelago; *L. dadyburjori* Menon, 1952 and *L. fasciata* Silas, 1958 from India; *L. lankensis* Deraniyagala, 1960 from Sri Lanka; and *L. insularis*, *L. ruhuna* and *L. varuna* described by Pethiyagoda et al. (2008) from Sri Lanka.

In Bangladesh, Ataur Rahman (2003) reported that *L. laubuca* is the only species of genus *Laubuca* found in the country area.

In October 1995, the inland aquarium fish collector who caught all the specimens of *Laubuca* employed in this study (collection site: Brahmaputra River, Bangladesh), sent these specimens to the Inland Fisheries Resources Research and Development Institute, Department of Fisheries, Thailand [NIFI] under the name *L. laubuca* [NIFI 2799].

In 2012 after having reviewed all the specimens sent by Mr. Kittipong Jaruthanin, we concluded that these fish are significantly different not only from specimens belonging to *L. laubuca* as described by Ataur Rahman (2003) from Bangladesh, but also from all other species of *Laubuca* hitherto known, by the combination of the following characters: lateral line scales, transverse line scales, body depth, caudal peduncle depth, fin rays and the absence of tubercles on lower jaw.

Hence, the population collected from Brahmaputra River is described herein as a new species.

Laubuca brahmaputraensis n. sp.

EXAMINED MATERIAL. Holotypus, NIFI 4532: Brahmaputra River, Bangladesh, 12.X.1995, legit Kittipong Jaruthani, (Fig. 1); Paratypi, NIFI 2799: 2 specimens, same data of holotypus.

DESCRIPTION OF HOLOTYPUS (sexual external characters cannot be specified). *L. brahmaputraensis* n. sp. is slender, body depth is 26.1%SL. The fish is very compress, body width is 8.7 %SL. Scales in lateral series are medium to large, lateral line scales include 31 + 1-2 scales, transverse line scales on body comprises ½6 - ½7/ 1 / 2½ -3½ scales and predorsal scales are 16. Head length (HL) is 24.1 %SL, head depth (HD) is more than half of body depth (BD) and head length (66.6 %BD or 72.2 %HL or 17.4 %SL). The eye is large, eye diameter is 36.1 %HL (50.0 %HD or 8.7 %SL). Post orbital length is 38.9 %HL (10.7 %SL), snout length is short, with 18.1 %HL (4.3 %SL) and interorbital width is 51.4 % HL (12.4 % SL) longer than postorbital width (44.4 %HL or 10.7 %SL).

Dorsal fin origin is posterior behind anal fin origin, predorsal fin length is 66.9 %SL, prepectoral fin length is 31.4 %SL, prepelvic fin length is 48.2 %SL and preanal fin length is 66.9 %SL. Caudal peduncle depth is 9.8 %SL. Pectoral fin is long but not reaching beyond the anus, the pectoral fin length is 31.4 %SL and 9 branched fin rays.

Pelvic fin is short not reaching beyond anus, the pelvic fin length is 20.1 %SL and 5 branched fin rays. Anal fin base is longer than dorsal fin base, the anal fin base length is 28.4 %SL, dorsal fin with 3 unbranched rays and 8 branched rays and anal fin with 3 unbranched rays and 19½ branched rays. The dorsal fin base length is 12.7 %SL.

VARIABILITY. 30.7-33.9 mm SL. Variation of male and female are unknown.

ETYMOLOGY. from Brahmaputra River, Bangladesh, where this species was collected.

DISTRIBUTION. This species is known only from Brahmaputra River, Bangladesh.

COMPARATIVE NOTES. *L. brahmaputraensis* n. sp. is distinguished from other species of genus *Laubuca* by the combination of the following characters: lateral line scales complete, with 31-32 + 1-2 scales;

transverse line scales on body showing ½6 - ½7/ 1 / 2½ - 3½ scales; body is slender, body depth is 25.1-29.3 %SL; caudal peduncle depth is 8.9-9.8 %SL; anal fin with 3 unbranched rays and 19½-20½ branched rays; pelvic fin is short (43.2-83.3 %HL) not reaching beyond the anus; a black blotch above the pectoral fin base; lower jaw smooth, lacking tubercles on skin.

Particularly, *L. brahmaputraensis* n. sp. is clearly different from *L. caeruleostigmata* of Thailand in many characters: body depth is 3.4-4.0 times SL (in *L. caeruleostigmata* is 2.25), lateral line scales includes 31-32 scales (vs 34-35 scales in *L. caeruleostigmata*).

Moreover, *L. brahmaputraensis* n.sp. has one black blotch above the pectoral fin base (vs. 4-5 dark vertical stripes above pectoral fin base on sides of body in *L. caeruleostigmata*) (Smith, 1931; Smith, 1945; Silas, 1958).

L. brahmaputraensis n.sp. is different from other species of genus *Laubuca* of Sri Lanka by the combination of the following characters: lower jaw smooth, lacking tubercles on skin (vs. some densely tubercles in *L. insularis* and *L. lankensis*); pelvic fin is short not reaching beyond the anus (vs. a long pelvic fin reaching beyond posterior anal fin origin in *L. insularis*); body depth is 25.1-29.3 %SL (vs. 32.8-34.6 %SL in *L. ruhuna*, 27.9-32.4 %SL in *L. varuna*, 27.2-29.8 %SL in *L. lankensis*, and 26.0-28.8 %SL in *L. insularis*); anal fin is 19½-20½ branched rays (vs. 15½ -17½ in *L. varuna*, 17-18½ in *L. ruhuna*, 17½ -19½ in *L. insularis*, and 16½-20½ in *L. lankensis*) (Pethiyagoda et al., 2008).

L. brahmaputraensis n.sp. is distinguished from *L. dadyburjori* of India by a complete lateral line scales (vs. an incomplete one in *L. dadyburjori*).

L. dadyburjori has a black stripe on lateral series, with 2-5 black circular spots on it, the stripe is extend from the anterior of eye to caudal peduncle whereas *L. brahmaputraensis* n. sp. does not show any black stripe along the body (Menon, 1952; Silas, 1958). *L. brahmaputraensis* n. sp. is distinguished from *L. fasciata* of India by short pelvic fin not reaching beyond the anus (vs. a long pelvic fin reaching beyond the anus in *L. fasciata*), lower jaw smooth (vs. scattered tubercles in *L. fasciata*), a black blotch above the pectoral fin base (vs. a black longitudinal stripe in *L. fasciata*); anal fin shows 19½ – 20½ branched rays (vs. 14½ - 16½ in *L. fasciata*) (Pethiyagoda et al., 2008; Silas, 1958).
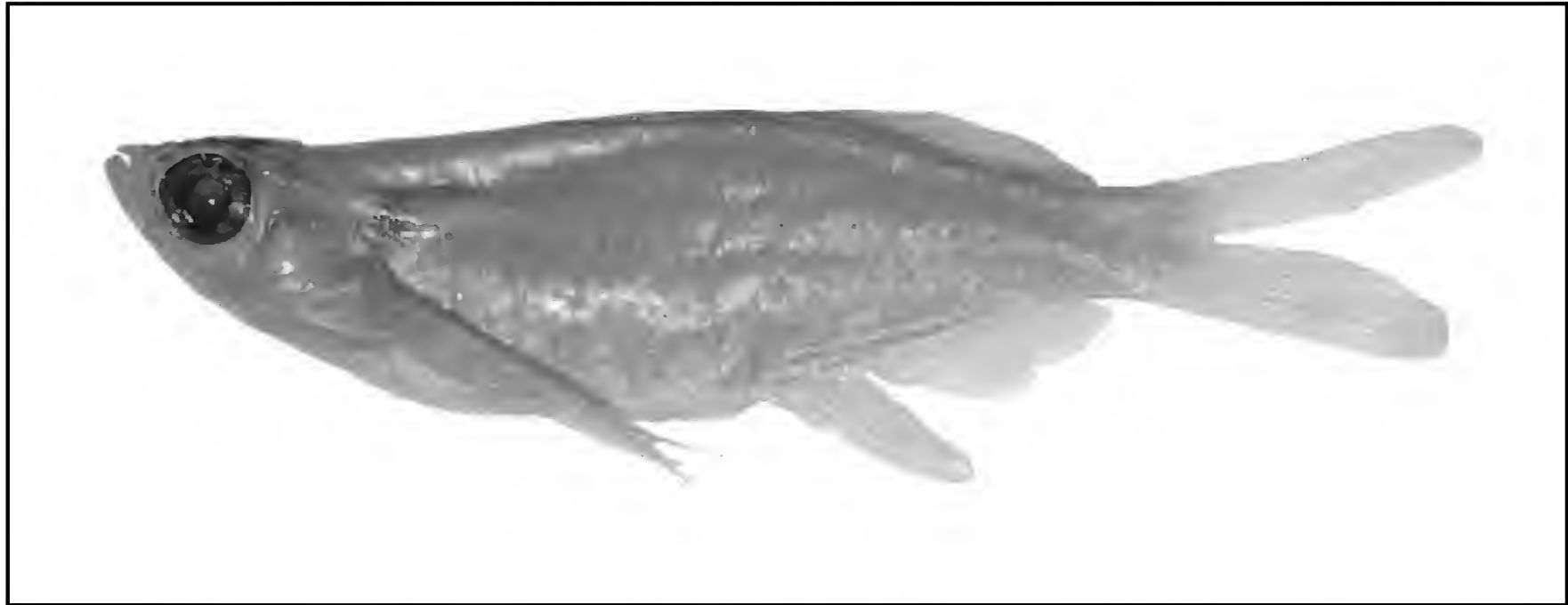
Figure 1. *Laubuca brahmaputraensis* n. sp. from Brahmaputra River, Bangladesh.

L. brahmaputraensis n. sp. is distinguished from *L. laubuca* of Bangladesh by body depth which is 3.4-4.0 times SL (vs. 2.7-3.3 times SL or 3.5-4.2 times total length,TL, in *L. laubuca*), lateral line scales comprises 31-32 scales (vs. 34-36 in *L. laubuca*), branched anal fin rays include 19½-20½ branched rays (vs. 18-19 in *L. laubuca*), predorsal scales are 16-17 (vs. 20-21 in *L. laubuca*) (Ataur Rahman, 2003).

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